

Twin Cities Walking Study
Environment and
Physical Activity:
GIS Protocols
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Editor: Ann Forsyth

Contributors (alphabetically):

Ann Forsyth, PhD

PI, RWJF ALR Grant, Metropolitan Design Center/College of Architecture and Landscape Architecture

Joel Koepp

GIS Research Fellow, Metropolitan Design Center

J. Michael Oakes, PhD

Co-PI RWJF ALR Grant, School of Public Health

Kathryn H. Schmitz, PhD

Co-PI RWJF ALR Grant, School of Public Health

Jason Zimmerman

GIS Research Fellow, Metropolitan Design Center

Extra material from:

Daniel Rodriguez and Yan Song, University of North Carolina

Twin Cities Walking Study, Metropolitan Design Center
1 Rapson Hall, 89 Church Street SE, Minneapolis, MN 55455-0109, USA
<http://www.designcenter.umn.edu>, Forsyth@umn.edu.

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T h i s i s a w o r k i n p r o g r e s s

TABLE OF CONTENTS

1. CONCEPTUAL ISSUES	6
Chapter by: Ann Forsyth (major draft), Michael Oakes (statistics and sampling), Kathryn Schmitz (measurement); fact checking by Joel Koepp (data), Jason Zimmerman (data).	6
1.1. Protocol Purposes and Audiences.....	6
1.2 Organization of the Protocols Manual.....	7
Additional Information on this Version of the Manual.....	8
1.3 The Context of the Manual: The Twin Cities Walking Study	9
1.4 Steps in Developing the Manual.....	10
1.5 Data.....	11
Problems.....	11
U.S. Census	12
MetroGIS	12
Ramsey County, Cities in Ramsey County, and I-35W Corridor Coalition	13
Excensus	14
Digitized Street Trees, Street Lamps, and Sidewalks.....	14
Irvine-Minnesota / Modified Boarnet-Day Inventory	14
1.6 Measurement Units	15
1.7 Measurement Logistics	15
1.8 General Measurement Geographies.....	17
1.9 Creating the Initial Focus / Context Area Study Geography for the Twin Cities Walking Study.....	17
Major Decisions	17
Deciding to Look at the Residential Environment	18
Deciding to Recruit from and Measure Specific Places Rather than Sampling People from Across the Metropolitan Area.	18
Using a Grid to Demarcate Neighborhoods Rather than using “Natural” Neighborhoods, Census Geographies, etc.	18
Stratifying by Density and Street Pattern, Rather than Other Factors such as Mixed Use or Pedestrian Infrastructure	19
Things We Would do Differently	21
1.10 Definitions of Terms.....	21
2. FUNDAMENTAL PROTOCOLS AND PROCEDURES.....	24
Chapter by: Ann Forsyth (drafting, conceptual issues and formulae, some comments and GIS approach text); Joel Koepp and Jason Zimmerman (GIS Steps and the rest of the comments and GIS approach text).....	24
Background.....	24
2.1 Net Land Area (without water)	24
2.2 Gross Area (including water).....	25
2.3 Creating a Focus Area Sampling Grid and Sampling Extreme Areas (followed by randomly sampling addresses).....	26
2.4 Measurement Geography Type 1: Grid Cell.....	29
2.5 Measurement Geography Type 2: Straight Line or Airline Buffer	31
2.6 Measurement Geography Type 3: Network or Street Distance Buffer	34
2.7 Measurement Geography Type 4: Straight Line or Airline Distance to Nearest Feature ...	36
2.8 Measurement Geography Type 5: Network or Street Distance to Nearest Feature	38
2.9 Measurement Geography Type 6: Parcel of Residence	39

3. DENSITY	41
Chapter by: Ann Forsyth (drafting, conceptual issues and formulae, some comments and GIS approach text) and Joel Koepp (GIS Steps and the rest of the comments and GIS approach text).....	41
Background.....	41
3.1 Raw Population per Unit Land Area	42
3.2 Population per Unit Land Area (without water)	44
3.3 Population per Developed Land Area (without water).....	46
3.4 Residential Population in Residential Parcels (Residential Density) (without water)	50
3.5 Population plus Employment per Unit Land Area (excluding water)	52
3.6 Employment per Unit Land Area.....	55
3.7 Housing Units per Unit Land Area (gross, census data) (without water).....	56
3.8 Lot Coverage (without water).....	58
The following variables are not proposed to be used in the study, so only a detailed formula is included.....	60
3.9 Housing Units per Unit Land Area (parcel data)--Not Used in Study	60
3.10 Housing Units per Unit Residential Land Area—Not Used in Study	60
3.11 Households per Unit Land Area (excluding water)—Not Used in Study	60
4. PEDESTRIAN INFRASTRUCTURE.....	61
Chapter by: Ann Forsyth (drafting, conceptual issues and formulae, some comments and GIS approach text) and Joel Koepp (GIS Steps and the rest of the GIS approach/ comments text).....	61
Background.....	61
4.1 Sidewalk Length per Unit Area	61
4.2 Sidewalk Length Divided by Road Length.....	63
4.3 Sidewalk Length per Length of Major Road.....	64
4.4 Street Lights per Length of Road.....	66
4.5 Street Trees (trees within an X distance buffer) per Length of Road	68
Note, the next variables use data from an urban design inventory that uses sample data and may need to be modified for 100% data	71
4.6 Percent of Street Segments with Marked Pedestrian Crossings at One or Both Ends.....	71
4.7 Percent of Street Segments with Visible Litter, Graffiti, or Dumpsters	73
4.8 Percent of Street Segments with Traffic Calming, Broadly Defined	75
4.9 Other fieldwork based measurements of neighborhood identification, street crossing, street characteristics, views, land uses, barriers, sidewalks, bicycle lanes, mid block crossing, steepness, sidewalk amenities, street trees, buildings, windows, other features of buildings, garages, parking, driveways, maintenance, lighting, freeways, traffic features, architecture/ design.....	77
4.10 Distance to Nearest Transit Stop	78
4.11 Transit Stop Density	79
The following variables are not proposed to be used in the study, so only a detailed formula is included.....	81
4.12 Percentage of Blocks with Full Length Sidewalks	81
4.13 Percentage of Blocks with Street Lights.....	81
5. LAND USE MIX	82
Chapter by: Ann Forsyth (drafting, conceptual issues and formulae, some comments and GIS approach text) and Jason Zimmerman (GIS Steps, many comments/ GIS approach text). Reference to additional materials by the team of Active Living Research grantees at the University of North Carolina, led by Daniel Rodriguez.	82
Background.....	82
5.1 Percentage of Total Parcel Area in Major Land Uses (seven land uses in this case).....	83

5.2 Percentage of Land Area in Night Time Uses	86
5.3 Percentage of Land Area in Social Uses	88
5.4 Percentage of Land Area in Retail Uses.....	90
5.5 Percentage of Land Area in Industrial and Auto-Oriented Uses.....	93
5.6 Proportion of Dissimilar Land Uses Among Grid Cells by Cell, Formula 1	95
5.7 Proportion of Dissimilar Land Uses Among Grid Cells in an Area, Formula 1	107
5.8 Dissimilarity Index, Formula 2 (new in Version 2.1).....	109
5.9 Entropy Index (new in Version 2.1)	112
5.10 Herfindahl-Hirschman Index, HHI (new in Version 2.1)	114
Employment Per Unit Land Area (see 3.6 in density section).....	115
5.11 Retail Employment per Unit Area.....	115
5.12 Density of Employees in Major Retail Subcategories (Separate Measures): General Merchandise (old SIC 53xx); Food Stores (54xx); Eating and Drinking Places (58xx); Miscellaneous Retail (59xx).	117
5.13 Distance to Nearest Facility with Employees in Major Retail Subcategories (Separate Measures): General Merchandise (old SIC 53xx); Food Stores (54xx); Eating and Drinking Places (58xx); Miscellaneous Retail (59xx).	119
5.14 Distance to Nearest Facility for Comparison with NQLS Survey	121
5.15 Gravity Measure with Competition (new in Version 2.1).....	122
6. STREET PATTERN	124
Background.....	124
6.1 Average Census Block Area	125
6.2 Median Census Block Area	127
6.3 Ratio of Area within X Street Distance to Area within X Distance Radius	131
6.4 Number of Access Points.....	134
6.5 Road Length per Unit Area	137
6.6 Intersections per Unit Area	140
6.7 Ratio of 4-Way Intersections to All Intersections.....	144
6.8 4-way Intersections per Unit Land Area	151
6.9 Ratio of 3-way Intersections to All Intersections.....	152
6.10 Connected Node Ratio	156
6.11 Median Perimeter of Block.....	158
The following variables are not proposed to be used in the study, so only a brief description and detailed formula are included.	160
6.12 Link-Node Ratio.....	160
CHAPTER 7. OTHER BUILT ENVIRONMENT RELATED / SPATIAL VARIABLES	162
Initial outline by Ann Forsyth	162
Overview.....	162
Work Environments.....	162
Crime	162
Climate and Air Quality.....	163
Traffic.....	163
7.1 Proportion of High Functional Classifications	163
CHAPTER 8. DATA STORAGE AND SHARING	165
By Jason Zimmerman, Joel Koepp, and Ann Forsyth.....	165
Steps/problems with obtaining our data	165
Storing/Sharing data	166
Tracking changes/updates.....	167
Other issues	167
Projections.....	167
Converting Measures: Blocks and Minutes to Meters	167

APPENDICES	168
Appendix 1A: I-35W Corridor Coalition Land Use Metadata	168
Appendix 1B: Excensus Metadata	177
Appendix 1C: GIS Digitizing and Fieldwork for Street Trees, Street Lamps, and Sidewalks	178
By Joel Koepp	178
Appendix 1D: Matrix of Measures by Measurement Geography Used in Twin Cities Walking Study	181
Appendix 1E: Other Data and Measurement Issues.....	184
By Joel Koepp and Jason Zimmerman with Ann Forsyth.....	184
1. Projections	184
2. Transformation of Raw Data to Final Form	184
Appendix 1F: Detailed instructions for Downloading and Cleaning Census Data	186
By Joel Koepp	186
Appendix 4A: Modified Boarnet-Day Inventory, Now the Irvine-Minnesota Inventory	191
By Ann Forsyth drawing on collaborative work by Kristen Day, Marlon Boarnet, and Mariela Alfonzo.....	191
Appendix 5A: Ramsey County Land Use Codes	200
Appendix 5B: I-35W Corridor Coalition Land Use Codes.....	203
Appendix 5C: Determining Land Uses for Context Areas and Buffers	204
By Jason Zimmerman	204
REFERENCES.....	207

1. CONCEPTUAL ISSUES

Chapter by: Ann Forsyth (major draft), Michael Oakes (statistics and sampling), Kathryn Schmitz (measurement); fact checking by Joel Koepp (data), Jason Zimmerman (data).

Note, this chapter has had only minor revisions compared with versions 2.0 and 2.1. However, additional information about data storage and sharing were included in Chapter 8 in version 2.2.

1.1. Protocol Purposes and Audiences

This manual provides protocols for measuring environmental variables associated with walking. It reflects work in progress. This is version 2.2 of the manual. Version 3.0 will be completed during the late summer of 2005.

The manual has four purposes.

- It records the methods for environmental measurement used in the Twin Cities Walking Study so that the research team can replicate its own findings at a later date and so different measurement staff share common definitions and processes. GIS systems are so multifaceted that seemingly simple decisions made at one time have ramifications for future work. Without a formal communications mechanism that makes such decisions explicit and organizes them errors can be left unrecognized, compounding measurement problems.
- The documents methods for replication. The funder of the Walking Study, the Robert Wood Johnson Foundation (RWJF), expressed interest in documenting methods well enough to have at least some measurements replicated across other RWJF study teams in order to allow later meta-analysis.
- It provides a preliminary prototype for other such manuals that may be produced by different teams. However, it is also possible for other teams to merely modify this manual, with attribution.
- The manual aims to make GIS research methods and data sources less opaque, particularly to public health researchers who have not used such data.

These four purposes correspond to the audiences for this manual: (1) the initial research team, (2) other RWJF grantees, (3) other research groups doing this kind of environmental measurement, and (4) researchers not particularly familiar with GIS but interested in understanding the strengths and limitations of GIS-based measures of environmental features potentially correlated with physical activity.

It responds to a general problem in the literature on measuring environmental features thought to be associated with physical activity—that is, a lack of standards for how to define key measurement variables. While there are notable exceptions that we cite in particular protocols, researchers rarely provide detailed formulae for the calculations of specific variables or even their detailed approach to conceptualization (e.g. was water included in the land area calculations). Further, few publication venues are available for explaining the details of measurement that are highly dependent on the capacities of specific Geographic Information Systems software.

1.2 Organization of the Protocols Manual

The manual is in six sections.

- Chapter 1, on conceptual issues, deals with the organization of the manual, how it was produced, data sources, and measurement geographies.
- Chapter 2 includes protocols for measuring items that are not in themselves possible measures of walkability, but that are components of such measures. An example is land area.
- Chapters 3 through 6 look in turn at measurements of density, pedestrian infrastructure, mixed use, and street patterns.
- Chapter 7, new in version 2.2, outlines some measures of variables related to the built environment e.g. traffic and safety.
- Chapter 8 examines a number of crucial issues related to data storage and sharing.
- Appendices and references are at the end of the manual.

Protocols themselves take a specific format. Each one contains six main parts:

1. Basic Concept: This is a very rudimentary idea, often backed up by references to the literature from which it is drawn. While it is very rudimentary, in journal articles it is quite common to find it as the only type of description of a variable.

E.g. gross population density, without water, is the overall residential population divided by the land area.

In this protocol manual, this section also cites sources as to why this variable is important as a measure of the environment.

2. Basic Formula or Basic Definition or, in one case, Basic Procedure: This provides a more specific formula or definition.

E.g. Population per Unit Land Area (without water) = Persons in housing units per unit gross area excluding water.

3. Detailed Formula or Detailed Definition: This provides a more specific formula that includes data sources or a more detailed definition.

E.g. Population per Unit Land Area (without water) = Persons in housing units as measured in the US Census at the block level per unit land area excluding area of water features as measured in the Ramsey County layer or the Metropolitan Council water layer for areas outside Ramsey (with the nature of these layers explained, e.g. Ramsey County includes all visible water).

4. Comments and Explanations. These include answers to more detailed questions that will likely arise as measurements are made. This is also the location for warnings about potential sources of error.

E.g. Where census blocks are cut by the end of the measurement geography, the population is apportioned according to the percentage of land area falling inside and outside the line.

The Ramsey County water layer includes all water visible in very high resolution digital orthophotos, though not such features as swimming pools (see more detail in chapter 2)]. For the one area outside Ramsey County We used the Metropolitan Council's 200 Water Feature Layer (again, more details are in chapter 2).

5. *GIS Approach*: This section outlines the big steps involved in making the measurement. An expert GIS user could work from this list to perform the measures and would need to do so if using software other than the ESRI ArcGIS suite of software.

6. *GIS Steps*. The GIS steps section, in smaller print, involves detailed GIS instructions using ArcGIS 8 or ArcGIS 9 and designed to be comprehensible by someone who does not use GIS every day (e.g. a principal investigator). The study team completed them for four main reasons:

- They mean that the team didn't have to reinvent the wheel when going back to do measurements a second time
- They allowed investigators and other GIS fellows, to discuss how well the GIS functions actually represented the concepts being measured
- They allowed some measurements to be conducted by lower level users such as research assistants (and principal investigators)
- They also allowed us to avoid some inconsistencies—for example when locating the centroid of crescent shaped polygons, one function in ArcGIS 8 allows it to be outside the polygon and one does not. Because we had recorded the exact function we used, we were able to check that we had been consistent in this measurement.

It should be noted that these steps often indicate one of several ways to do measurements.

In addition, after version 1.0 of this manual was completed we were forced by university policies to upgrade our GIS to ArcGIS 9. To do this we had to uninstall ArcGIS 8. This manual is still largely based on ArcGIS 8 but will gradually be converted to ArcGIS 9.

Additional Information on this Version of the Manual

This is version 2.3 of the protocols. There are a number of refinements that we will undertake in upcoming versions.

- *Links to the Literature*: These measures are based on a systematic review of the literature. The sources, uses, and limits of variables and measurement approaches have been tracked in our internal documentation. However, this version does not reflect all this work. Later versions will be increasingly complete in this area or will refer to other papers to be published by the Twin Cities Walking Study team.
- *GIS Steps*: We are continually experimenting with automating more steps.
- *GIS Steps*: Because this work in progress, at least some of the GIS steps have only been tested once, by the person who wrote them, and feedback will be welcome. In addition, some were developed for ArcGIS 8 and have not yet been converted to ArcGIS 9.

1.3 The Context of the Manual: The Twin Cities Walking Study

The manual was written in the context of a research project measuring the walkability of residential environments in the environmentally diverse northern sector of the Minneapolis-St. Paul metropolitan area.

Partly in order to undertake additional environmental fieldwork in areas known to be environmentally diverse, and partly due to recruitment logistics for the people in the study, the research focused on 36 discrete *focus areas*, 0.5*0.5 miles (805*805 meters) in size, selected for variation along two dimensions hypothesized to be important for physical activity: (A) gross population density (B) street pattern (measured as median block size).ⁱ The study sites were selected to represent a subset of the most extreme areas—ranking high or low on each of these two dimensions—nine sites with high density and small blocks, nine with high density and big blocks, nine with low density and small blocks, and nine with low density and big blocks. Low population density was set at below 5 persons per gross acre (12.4 per hectare) for a 0.5*0.5mile (805*805 meter) area, high density we defined as 10 per acre (24.7 per hectare) and above. All density calculations excluded the land area covered by water, an important issue in Minnesota. Small median block size was defined as below 5 acres (2.0 hectares) which was related to standard block sizes in the area. Large blocks were larger than 8 acres (3.2 hectares). Areas also had to have at least 18.75 percent of their land area in residential land use and a population of at least 200 (paragraph adapted from Forsyth et al 2004a).ⁱⁱ

In each focus area, approximately twenty residents were recruited to wear a motion detector (an accelerometer) for seven days, complete a seven-day travel diary, have their height and weight measured, and answer a number of surveys dealing with demographic, attitudinal, and socioeconomic issues (Forsyth et al 2004a). The final total was 717 and 20% had repeated the measures. This is one of the first large studies to have very detailed objective physical activity measurement and very detailed environmental measurement.

Several aspects of this study are important to understand when using this manual:

- *Results yet to come:* At the time of preparing this version (2.3) of these protocols, all data collection is complete and much measurement of environmental variables but analysis is not yet complete. That means that we do not yet know which of these measures matter.
- *Utilitarian walking:* The study focused on utilitarian walking—earlier research indicated that such walking is most affected by environment (compared with recreational walking, for example). While the study is measuring all kinds of walking and physical activity through accelerometry (motion detection), surveys, and a travel and walking diary, the environmental measures were selected through the lens of those features most likely to be associated with utilitarian walking (working for transportation to work, errands, etc). The main focus of the research is on the residential environment although as data were collected on work environments, where applicable, many measures were also applied to those environments.
- *Four categories of measures:* Based on a review of earlier research, the study proposed that four kinds of variables might be associated with how much people walk: population density, pedestrian infrastructure and amenities, mixed use or destinations, and street pattern or connectivity. However, we are cast our net very widely in terms of actual environmental measurements and will add more transportation related measures in a later version. One of the results of the study will be better knowledge about which

environmental variables are most correlated with measured walking and other physical activity at what scales. However, the study is also measuring a variety of other variables correlated with walking including those with a spatial component (traffic) and those that are more purely social or psychological.

- *GIS data:* The study area was selected because it had excellent GIS data. However, we still faced some difficulties with less consistent data on the edge of the study sector, and with specific topics such as street trees and sidewalks that were not collected consistently. Specific data issues are discussed below.
- *Urban design inventory:* As RWJF funding recipients, we promised to build on an earlier round of RWJF funding to develop measurement instruments. Of the measurement grants involving original data collection, one draft inventory was available at the time of our data collection—the inventory by a team led by Marlon Boarnet and Kristen Day or UC Irvine. The Twin Cities Walking Study team modified this inventory and the two groups are currently combining inventories into what will be the Irvine-Minnesota inventory (Forsyth et al 2004a; Day et al. 2005). This inventory is based on a sample of road segments, for focus areas and a 0.25 mile (402 meter) buffer around them, and some protocols deal with these sampled segments.

1.4 Steps in Developing the Manual

The Twin Cities Walking Study essentially consists of three overlapping teams: environmental measurement; physical activity measurement; and statistics. This manual was developed primarily by and for the environmental measurement team, though with input from and in coordination with the other two teams. In addition, it enabled the three teams to communicate clearly about environmental measurements.

The manual was developed in several steps:

- *Listing and revising the list of variables:* A list of variables was developed based on variables used in research to date. Additional variables were added related to those that should be important according to the literature, modified by what data were available. This was revised a number of times to reflect recent developments in the literature, the availability of new data, developments in our own research, and to coordinate with other RWJF grantees.
- *Creating the basic formulae:* Where variables had been used by others, these sources were reviewed and are cited. Drawing either on this literature, or working from first principles or at a more conceptual level, the equivalent of the “basic concept” and “basic formula” were developed (see section above). These two steps were mostly done by Ann Forsyth, with useful input from Kathryn Schmitz and Michael Oakes. It should be noted that this version does not contain citations for every instance of use of particular measures. We will be incorporating them incrementally in subsequent versions but cannot hope to find all uses. If readers have used some of these measures and want to be cited, please email the editor of this manual.
- *Troubleshooting the details:* At this stage the GIS technical team was brought on board to develop more detailed methods for measuring the variables, trying them out on focus and context areas as the final set of participant addresses was not yet known and many of the buffer measures could not be developed (see below for an explanation of measurement geographies). Operationalizing many of the measurements was not at all

straight forward. The kinds of issues dealt with included those we outline in the “detailed formula” and “comments and explanations” sections of the protocols. The issues were discussed in weekly GIS team meetings that were partially minuted, emails, and via research logs. These modes of recording are discussed in more detail in section 1.7. While Ann Forsyth had the final say on measurement, Jason Zimmerman and Joel Koepp did very important work identifying problems and discussing how to operationalize measurements in GIS.

- *GIS Work*: GIS strategies were then written by Jason Zimmerman and Joel Koepp, and are in two forms. The *GIS Approach* section gives an overview of tasks, and the *GIS Steps* are intended to be useable by moderately trained GIS users.
- *Assembly and refinement*: At this stage the protocols could be assembled, edited, and refined. This version of the protocols is part of that development stage, allowing protocols to be tested operationally and reviewed to ensure that the detailed measurement steps fully reflect the concepts. The protocols can also be tested by others who may also offer critiques.

Note, authorship is indicated in each chapter as a way of enhancing internal coordination in the study team.

1.5 Data

Problems

There are a number of problems with available GIS data, apart from common errors (see Forsyth et al. 2005a).

Geographies: Different environmental variables are measured using different geographies e.g. parcels, blocks, street segments. Not all data are available for very small geographical areas—for example much economic data is only released in aggregate form. However, it is possible to have very small aggregations constructed—akin to census blocks.

Consistency: GIS data are not consistently collected across the United States or even within municipalities. Where national data are available these protocols can be used directly. Where this is not the case, care needs to be taken in transforming the data that do exist, collecting new data, or limiting inappropriate comparisons where data cannot be matched.

Purpose: Most GIS data are not collected to answer questions about physical activity and the built environment but are rather collected in order to manage infrastructure investments, collect taxes, keep government records, and manage transit systems.

Accuracy: Different kinds of data are available at accuracy, many used for broad environmental monitoring and not accurate enough for research into physical activity e.g. tree coverage data at the 1-2 ha level.

Completeness: Many forms of data are only available for part of the environment—from urban design inventories using a sample to traffic counts only available for major roads.

Time: Data are complicated to collect so are only available for certain times so it is common for parcel data, roads, and aerial photos to come from slightly different times and thus be slightly different to each other.

Finally, where data are collected, they are not always freely available. Conducting a study such as the Twin Cities Walking Study involved a number of separate data licensing agreements and thousands of dollars in direct purchasing costs.

Specific data sources that we used included:

U.S. Census

www.census.gov

Description: SF1 files at the block and block-group level and SF3 at the block group level.

Metadata: Metadata for census variables are available in a number of parts of the census web site. For details on downloading large SF# files see

<http://www.census.gov/support/SF3ASCII.html>

MetroGIS

www.metrogis.org

www.datafinder.org

Description: This is the GIS group supported by the Metropolitan Council of the Twin Cities, a state agency that does planning and analysis for seven counties at the core of the Twin Cities metropolitan area. Their data include a number of useful layers complete with metadata and accessible from <http://www.datafinder.org/catalog.asp>. Not all data are free and many require specific agreements to be made between the user and the data owner:

General data (useful but not as detailed as Ramsey/I-35W data)

[2000 Digital Orthophotos](#) (2 foot per pixel resolution)

[Generalized Land Use, 2000](#)

[Counties, Cities and Townships](#)

[MetroGIS Regional Parcel Dataset - Current \(updated quarterly\)](#) (unavailable in 2004 due to a legal dispute but made available in 2005)

[Water Features from 2000 Land Use Data](#) (supplements Ramsey County water layer)

Parcels beyond Ramsey

[Anoka County Parcel Layer](#)

[Dakota County Parcel Boundaries](#)

[Hennepin County Parcel Layer](#)

The Lawrence Group (TLG) Data—Streets, Points of Interest, and Census

[Census Geography 2000 – TLG Aligned; Blocks, Block Groups & Tracts](#) This is the MetroGIS endorsed version of the census data and the one we used. It has the census geographies better aligned with the TLG road layer

[TLG Landmarks – Areas of Interest](#)

[TLG Landmarks – Lines of Interest](#)

[TLG Landmarks – Points of Interest](#)

[TLG Street Centerline Edits Table](#)

[TLG Street Centerlines and Address Ranges](#)

Buses

[Bus Route Segments](#)

[Bus Routes](#)
[Bus Service](#)
[Bus Shelters](#)
[Bus Stops](#)
[Transit Centers](#)

Other

[Regional Trails – Existing and Proposed](#)

Metadata: Most are available linked to the data finder web site at
<http://www.datafinder.org/catalog.asp>

Ramsey County, Cities in Ramsey County, and I-35W Corridor Coalition

<http://www.ramseygis.com/Webpages/>

<http://www.i35w.org/gis.html>

City of New Brighton
Boulevard Trees
Sidewalks

City of Roseville
Sidewalks

City of St. Paul
Lighting (incomplete)
Park Property
Recreation Centers
Sidewalks (incomplete)
Street Trees (incomplete)

Description: We used local data from two overlapping sources—The I-35W Corridor Coalition, a group of seven suburban municipalities that had cooperated to produce very consistent GIS data. Six of the cities were in Ramsey County. Ramsey County had created a data guide with much of the metadata. The I-35W Corridor Coalition had a GIS consultant who provided other Corridor metadata via email. In general, Ramsey County had a great deal of fairly well documented data, including very recent high resolution digital orthophotos (resolution of one foot per pixel). However, the I-35W Corridor Coalition had some already existing Excensus data (see below) and while Corridor land uses were in broader categories than Ramsey County they were updated more regularly.

The following list gives a sense of the sources available in Ramsey County, which has produced a data guide (Roman 2001). The Coalition member in Anoka County sometimes lacked some of these data layers (although in our case, only one focus area fell in Anoka). Data include:

- Parcel boundaries: County assessors and surveyor's records, updated monthly
- Physical features such as structures and water: Aerial photography, updated early 2002
- Digital Orthophotos: one foot per pixel photos from the county surveyor's office, 2003

- Land use data in six major land use classes (agriculture, industrial, commercial, residential, exempt which includes many public buildings, and other). Each major classification is further subdivided into between six and 50 detailed subclasses. For example the commercial land uses include about 50 subclasses such as “office building 1-3 stories,” “gas station,” “automotive service station,” community shopping center,” “restaurant, cafeteria, and/or bar” and “flex industrial center”. Some data subclasses are further subdivided and available at even more detailed levels, for example “Dairy Queen” or “TGI Fridays”

Metadata: Some metadata are available via the Ramsey County Data User’s Handbook, on line at <http://www.ramseygis.com/Webpages/Hand%20Book.html>. The I-35W Corridor Coalition has separate land use metadata (see Appendix 1A).

Excensus

<http://excensus.gritechnologies.com/about.pl>

Description: The employment data that we used evolved over time. At first we proposed using data from a private Twin Cities consulting firm, Excensus, that had created very small area data sets, often updated annually, compiled from state, county, and local government sources such as Minnesota postal files, and data from water utilities, driver’s licenses and vehicle registrations, the school district census, and property assessors. State employment data are also available but had to be aggregated and we selected a 100*100m (1 hectare) grid cell for aggregating data.

For some complex reasons, Excensus generally used Dun and Bradstreet data for our study, checked these data against other sources. We then used the original point files and did not aggregate into 1 hectare cells.

Metadata: See Appendix 1B.

We also collected or mapped new data.

Digitized Street Trees, Street Lamps, and Sidewalks

Description: There were no consistent street tree, street lamp, and sidewalk data. Working from the Ramsey County digital orthophotos we first digitized these for all study areas and then field checked them. In a few cases we had data from cities but these also needed to be checked and updated. Digitizing was done by research assistants but checking of all data was done by a GIS Research Fellow.

Metadata: See Appendix 1C.

Irvine-Minnesota/Modified Boarnet-Day Inventory

Description: The research team used a 160+ question inventory to collect information about urban design features and pedestrian infrastructure in 20% of street segments. The Twin Cities Walking Study Team modified an inventory prepared by another team of researchers from UC Irvine. More information is available in (Forsyth et al 2004a). The two versions are currently being combined and will be available on the Active Living Research site in 2005. They are currently available in draft form at <http://webfiles.uci.edu/kday/public/index.html>.

Metadata: See Forsyth et al. (2004a) and forthcoming publications.

1.6 Measurement Units

In the US there is a decision about Metric or Imperial/English units. Many people in GIS use both as we did in the study, although we migrated from Imperial to Metric. We used a 0.5*0.5 mile square focus area largely because in the study area it matched the arterial grid. We used feet in discussing many features that had been created in feet—from parcels to sidewalks. Miles were used in many of the standard surveys used in the rest of the project, and in the travel diary adapted from the National Household Travel Survey measures were in blocks and miles.

However, as we increasingly used measurements involving buffering of individuals, the measurement geographies became so idiosyncratic that metric made as much sense to use. Version 2.0 of these protocols is the first fully metric version (we hope!)

We were also saved by some easy correspondences that meant converting to metric meant that measurements were close to those that had been developed in Imperial/English units:

1 mile =	1609.3 meters (rounded to 1600 for measurements)
0.5 miles (half) =	804.7 meters (rounded to 800)
0.25 miles (quarter) =	402.3 meters (rounded to 400)
0.125 miles (eighth) =	201.2 meters (rounded to 200)
one sixteenth of a mile =	100.6 meters (rounded to 100)

1.7 Measurement Logistics

Another note concerns the organization and practices of measurement teams using these protocols. The protocols were in part designed for the Twin Cities Walking Study team's internal use. They make explicit the myriad of decisions that go into even fairly simple environmental measurement. In particular:

- They allow the investigators and GIS technical staff to communicate with each other so that it is clear that measures conform to the concepts being tested.
- They also help communication among the investigators.

We hope the protocols will both allow measurements to be replicated more accurately and streamline the technical process of measurement.

However, given the quite varied data availability and formats it is vital that the investigators and GIS technical staff communicate about variations as decisions that seem small and innocuous to GIS staff can alter measures in significant ways and concepts of interest to investigators may not be simple to operationalize with different GIS data. These protocols were one way of communicating about these issues, however, we also used (1) decision logs, (2) emails, and (3) minutes. An excerpt from a decision log is on the next page. Emails were the bases for some of the protocols. Minutes of weekly meetings focused on action items and major decisions and were also emailed. Emailed minutes of weekly project meetings are a standard procedure in the office.

Week ending: GIS decisions made:

02.06.04 Will not try to convert New Brighton street light layer to GIS due to complexity of conversion and time lost to process. Instead, will use printout as a reference when digitizing layers from the orthophoto (data is from 1986 and would need to be carefully checked anyway).

02.13.04 [None – prepared questions/issues related to GIS variables]

02.20.04 Census blocks used for calculations if center of block (centroid) falls within the site area (both focus areas and context areas).

average census block size – selected all census blocks that had their centers in the site areas; converted area (in meters) to acres by multiplying by 0.0002471; opened table in Excel and calculated average size

median census block size – selected all census blocks that had their centers in the site areas; converted area (in meters) to acres by multiplying by 0.0002471; opened table in Excel and calculated median size

02.27.04 We decided on the following set of rules regarding **access points**:

1. The first set of access points will be created from the intersections of all roads from the TLG data layer and the boundaries of the focus and context areas.
2. The second set of access points will remove points that result from intersections with Interstates as well as on- and off-ramps. It will also remove one access point from each pair of points created by parkways and other divided at-grade roads.
3. The third set of access points will remove the points in Set Two and also remove marginal points that are just inside the edge of the site boundary, do not extend into the site, and have no other roads with access into the site within 330 feet.

Set One was created in ArcMap and the points counted automatically for both the focus and context areas. Set Two was created by manually removing the Interstate, ramp, and divided road points. For Set Three, a buffer of 330 feet was created around each of the access point. Marginal points which did not connect to a road with access to the site within this distance were removed manually.

03.05.04 Revised decision about **access points** to remove Set Three, consideration of marginal points, from the analysis. Because the site boundaries were created based on a fixed grid system, a number of access points were left just inside or just outside the site boundaries. This opened the door to many subjective decisions about inclusion. It was decided that overall the number of these access points actually counted would balance out and we would not worry about trying to classify or analyze them further.

03.12.04 Method for determining **road lengths**:

1. Select 1st pass of non-contiguous polygons
2. Clip road layer to polygons (use selected features only)
3. Recalculate road lengths with XTools
4. Perform spatial join to assign IDs to road segments (if there are road segments that are common to more than one polygon – as with the

1.8 General Measurement Geographies

There are many possible measurement geographies for analyzing the walkability of an environment. Which geographies are used depends on:

- Data availability (e.g. some data are available only in aggregated format)
- The nature of the variable (for example, if walking to a corner store is thought to be a key motivation for walking for transportation, the distance to the nearest store may be more important than the percentage of a buffer area taken up by corner stores)

Typical geographies include the following and these protocols focus on those that are underlined:

“Objective” geographies independent of experience:

- Natural neighborhood, variously defined
- Existing measurement unit e.g. census tract, TAZ
- Large grid cell (e.g. 400-1600 meters)
- Small grid cell (e.g. 100-200 meters)
- Straight line or airline buffer (at different radii, e.g. 100, 200, 400 meters)
- Network or street distance buffer (at different radii, e.g. 100, 200, 400 meters)
- Straight line or airline distance to nearest feature
- Network or street distance to nearest feature
- Parcel of residence

Other geographies

- Perceived environment (from surveys/interviews)
- Experienced environment (from diaries, GPS)

The measurement geographies are described in more detail in Chapter 2.

Appendix 1D contains a matrix of measures by measurement geographies in the study.

1.9 Creating the Initial Focus/Context Area Study Geography for the Twin Cities Walking Study

This section explains the key decisions we made in creating the study geography for the Twin Cities Walking Study. This is important to include for two reasons. First, some people may wish to replicate our approach. Second, even if study teams choose a quite different strategy for selecting areas to study, understanding the scheme used in the Twin Cities Walking Study provides useful background to this list of protocols. More detail about how we did the actual work to select the focus and context areas is described in a protocol in chapter 2.

Major Decisions

Several major decisions shaped the overall study and in particular the selection of 36 0.5*0.5 mile (805*805 meter) square *focus areas* embedded in 1.0*1.0 mile (1609*1609 meter) *context areas*:

- Deciding to focus on residential environments rather than, say, work environments
- Deciding to concentrate on specific places rather than sampling people from across the metropolitan areas
- Using a grid to demarcate neighborhoods rather than using “natural” neighborhoods, individually defined neighborhoods, census geographies, etc.

- Stratifying by density and street pattern, rather than other factors such as mixed use or pedestrian infrastructure
- Choosing which density and street pattern measures to use

The section concludes with some reflections on things we would do differently if doing it again.

Deciding to Look at the Residential Environment

Some people in the US conduct most daily activities in their neighborhoods, but more people live their lives across a metropolitan area and daily walking activities are conducted in spatially diverse locations linked by motorized transportation. This poses dilemmas for analyzing the effects of environment. People from the same residential area may have vastly different levels of physical activity, partly depending on the pedestrian orientation of the distant locations where they work, shop, socialize, and recreate (Cervero and Gorham 1995). However, residential environments are important locations as they are used by everyone, not just paid workers.

However, in order to capture larger activity patterns, we used a seven-day travel diary (with format based on the National Household Travel Survey) in association with seven-days of readings from an accelerometer. Individual-level surveys also asked for the address of the work environment, allowing additional analysis of those places.

Deciding to Recruit from and Measure Specific Places Rather than Sampling People from Across the Metropolitan Area.

We decided to focus on specific areas, rather than a random sample from across a larger area, for three main reasons:

- *Finding extreme areas:* As outlined above, we looked at areas that were extreme in terms of gross population density and median block size.
- *Urban Design and GIS fieldwork logistics:* Because detailed measurements of environmental characteristics involved collecting and checking data, having 36 consolidated focus and context areas rather than a couple of hundred smaller cells made this data collection viable.
- *Recruitment and measurement:* By focusing on 36 areas we could target recruitment better and find a limited number of “neutral” places, such as community centers and libraries, in which to conduct face to face interviews..

Using a Grid to Demarcate Neighborhoods Rather than using “Natural” Neighborhoods, Census Geographies, etc.

Many earlier studies had examined neighborhoods defined as census tracts, or defined by such features as arterial roads. Instead we created a 0.5*0.5 mile (805*805 meter) grid across the entire area. The grid helped us get around some of the measurement and analysis problems associated with the differences in size and shape of these other geographies. However, we are also using a number of individualized geographies such as buffers around individuals for actual measurements so that we were not stuck with the relatively coarse grid for all measurements. We called the 36 0.5*0.5 mile (805*805 meter) grid cells that we ultimately selected for study our “focus areas.” Areas of 1.0*1.0 miles (1609*1609 meters) surrounding the focus areas were called “context areas.”

There were over 500 populated cells in the study area—of these we selected 36 (see more detail in Chapter 2).

We chose 805*805 meter squares as a workable size. The 0.25 mile(402 meter) and 0.5 mile (405 meter) radius from a nodal point is frequently used as a baseline for walkability. The focus and context areas reflect this scale and the specific size was chosen for three reasons related to the reasons for focusing on specific places mentioned above. This size of space bounds an area that

is small enough to be the focus for a person's pedestrian activity; large enough to have a reasonable population to sample; and, for much of the study area, arterial roads are laid out on a 0.5 or 1.0 mile (805 or 1609 meter) grid. This means that census blocks and block groups will have boundaries that match these grids making census analysis easier. A central consideration is that the amount of walking recommended for health benefits is 30 minutes on most days (USDHHS 1996), which translates to about two miles (or approximately 3200 meters) per day. However, since we are interested in walking for transportation in addition to walking for walking sake, we chose not to evaluate elements of the physical environment that would allow for a 30 minute, 3200 meter walking loop for the purpose of leisure time exercise. We assumed that there would be multiple transportation trips per day and that the addition of some transportation trips would contribute to, but may not fulfill completely, the accumulation of 30 minutes of brisk walking on most days.

Of course as Krizek (2003a; 2003b) points out, many commercial and civic uses are located at intersections of arterials, and thus in measuring mixed use one commercial area could be divided between four focus areas. However, these commercial and civic areas will still be within the context measurement area, and within buffers around individuals, and so the effects of these uses on walking will be considered explicitly in that analysis.

Stratifying by Density and Street Pattern, Rather than Other Factors such as Mixed Use or Pedestrian Infrastructure

We knew that there were many environmental variables that may matter in utilitarian walking. The study design selects two to stratify the sample: density (gross population density) and street pattern (median census block area). This was to maximize variation. The logic is described below.

Statistically, sampling is critical to both internal and external validity in observational designs. Consider that in order to best estimate effect of socio-environmental contexts on walking, we should randomly assign (randomly selected) people to a large number diverse contexts (or visa versa) and observe walking behavior with perfect measures. Although such an experiment is obviously not possible, the exercise reveals the importance of measurement error, variability across neighborhood contexts, and the requirement that similar people reside in each (i.e., assignment mechanisms). Without control over assignment mechanisms, researchers must appreciate that "like people" do not reside in diverse neighborhoods: the rich reside in one type of neighborhood, the poor another; whites in one, blacks in another; urbanites in one, farmers in another. In fact, it is such social stratification that defines neighborhoods, for the most part. This means that the background characteristics of residents (composition) are typically confounded with the contexts. It follows that our sampling goal was to maximize variability in contexts while minimizing variability in resident's background characteristics – a difficult (sampling) problem indeed.

Conceptually, we were interested in the effects of four dimensions of context: density, street-pattern, mixed-use, and pedestrian amenities or infrastructure. Units in each dimension may be classified into high, medium, and low levels but to maximize variability our interest here rests with only the high and low. We would have liked to sample neighborhoods in this space but that would have meant that we needed data in all of the $2^4 = 16$ cells of the sampling-matrix cells. Given known levels of social stratification, there is a high probability that many of the cells will have no, or very few, observable neighborhoods (Oakes and Rossi 2003; Oakes *In Press-a*). The upshot of this confounding is that inferences are "off-support" of the data and rely on strong assumptions. To avoid this, we will sample 2-space defined on density and pattern (4 sampling-matrix cells), and measured mixed-use and amenities as any other covariate, such as

with as percent white, percent poor, etc. This plan was to strike the proper balance between internal and external validity. We may make inference in the 4-space, but only with appropriate care and caution and an eye on actual observed data. By analyzing a number of measures of mixed use and pedestrian infrastructure as variables (co-variates), rather than using them in the sampling frame, this study could still examine the association of these characteristics with walkability.

Details about how the final 36 areas were chosen are described in Chapter 2.

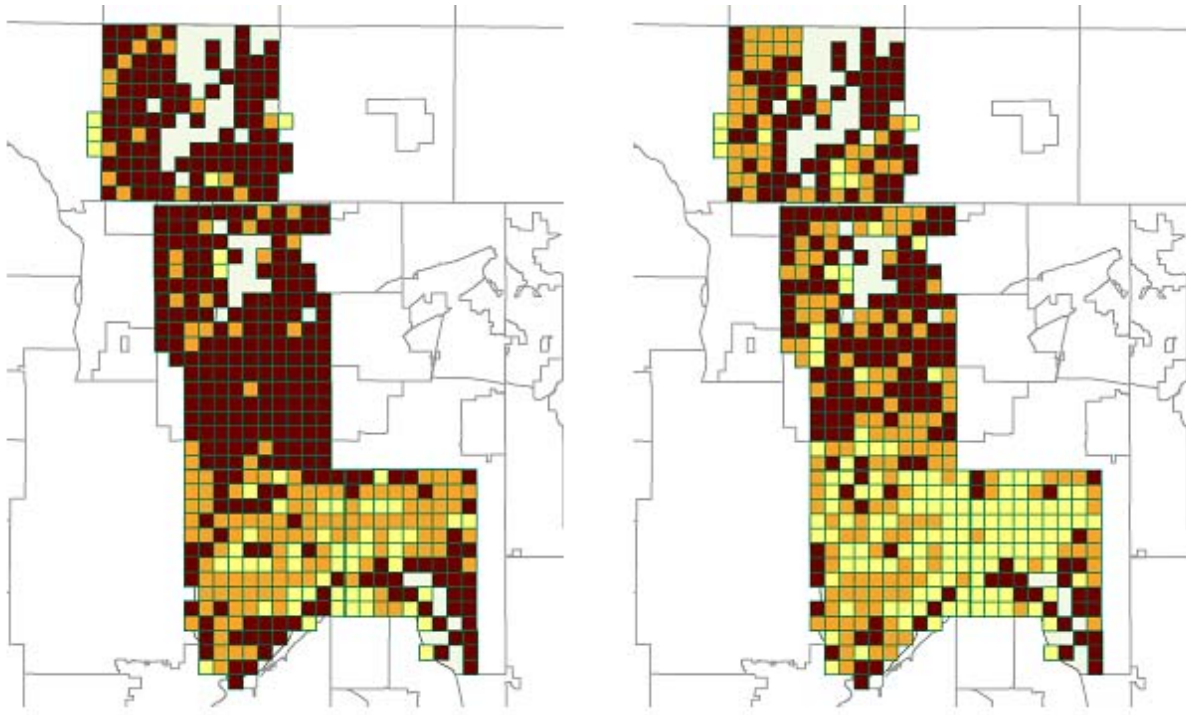
Our sampling plan may thus be characterized as a stratified cluster design, but unlike much work in survey sampling we had direct interest in cluster (i.e., PSU or primary sampling unit) effects. We staggered participant recruitment in each neighborhood to minimize any seasonality effects.

From the environmental perspective, the stratification ensured that there would be variation on many measures because some are correlated with the sampling frame variables (e.g. sidewalks go with small blocks), and others are rather randomly distributed (e.g. street trees are in most places).

Choosing which Density and Street Pattern Measures to Use

Once density and street pattern were selected for stratification we had to select one of the many measures of each of these. We chose gross density over, for example the density on residential parcels, because people walking through a neighborhood experience the whole environment, not just the residential part of the environment.

We chose block size as an easy measurement of connectivity. Our major innovation here was to use median block size—which is not totally straightforward in ArcGIS where average sizes are far easier to calculate. This was because statistically medians are a preferred measure of central tendency. In doing both measures we found significantly different distributions of means and medians.



Map on left shows average census block size for study area and on the right the median. Maroon = 8+ acres (3.2+ hectares), Orange = 5-8 acres (2.0-3.2 hectares), Yellow = 0-5 acres (up to 2.0 hectares)

In particular we picked up a number of areas with mostly small blocks but one large land use (e.g. a golf course or large industrial area) that gave them a medium *average* block size but a low *median* block size. They were thus included in our study.

Things We Would do Differently

There are a number of decisions that we would make differently next time.

Most importantly, we would not sample close to the edge of a county or other important data collection unit. We sampled from all 500 eligible areas, but that meant some of our sampled focus areas were right on the edge of a county, and the context area went into the next county. This added to our data collection efforts as we had to buy parcel data and match land use codes. While not overly onerous, it would have been simpler to avoid this.

1.10 Definitions of Terms

Context Area—1609*1609 meter area around a focus area, used for data collection.

Focus Area—805*805 meter area selected for study.

Study Area—the entire I-35W Corridor Coalition area plus St. Paul, from which 36 focus areas were selected.

Study Site—a smaller area, generally a focus or context area.

Several terms have a specific meaning in ArcGIS and are frequently used:

Summarize the data: involves creating a variety of “summary” statistics including the total sum of values but the same function can create a average, maximum, minimum, standard deviation, and variance but not a median.

Spatial join: this is joining map layers when their underlying attribute tables don’t share a common field—such as a parcel ID or census tract number--so they are joined based on location.

Intersect or spatial intersect: this procedure “sandwiches” two distinct data layers together, creating an output file combining the extent and features common to both layers. It preserves all boundaries, shapes, and attributes from both layers, so in the output a feature from one layer will typically be “cut” into multiple pieces by the boundaries of features from the other layer.

Appendix 1E contains some other relevant information such as coordinate systems used.

2. FUNDAMENTAL PROTOCOLS AND PROCEDURES

Chapter by: Ann Forsyth (drafting, conceptual issues and formulae, some comments and GIS approach text); Joel Koepp and Jason Zimmerman (GIS Steps and the rest of the comments and GIS approach text).

Note, the main revision to this chapter following version 2.0 was to Protocol 2.8 where steps were added; In version 2.2 additional information about sampling was added to Protocols 2.3.

Background

This chapter deals with issues fundamental either to other general measurements or to the Twin Cities Walking Study. These generally involve measurements of areas.

2.1 Net Land Area (without water)

1. Basic Concept

While it is easy just to measure total or gross area in a study geography (see next protocol), people generally do not walk on water. In locations with significant numbers of water bodies, a more useful version of the land area calculation excludes significant water bodies. This is of course particularly important in Minnesota which is just such a place, i.e. with many water bodies, even in urban areas. In other locations, total area would be appropriate.

2. Basic Formula

Net Land Area (without water) = Area within defined geography minus water bodies.

3. Detailed Formula

Net Land Area (without water) = Area within defined geography minus water bodies as interpreted by Ramsey County and the Metropolitan Council (for the one study site we had in Anoka County).

4. Comments and Explanations

The water area was defined differently by Ramsey and Anoka Counties. Fortunately we only had one focus (study) area in Anoka, and slivers of context areas in Anoka, Hennepin, and Dakota, all without a great deal of water.

The definitions included:

Ramsey County: "This data set primarily contains open water areas including creeks, lakes and rivers. Open water areas are derived from aerial photography observation and interpretation utilizing stereo processing techniques. Vector line work was originally stereo plotted from 2003 photography. All graphical lines contain a character based a layer name that identify the different mapping features. The flight height for the aerial photography utilized in this project is approximately 5000 feet [1,524 meters]. The mapping scale for aerial photography utilized in this project is 1 inch equals 833 feet [1 meter equals 10,000 meters]. All features of this type photogrammetrically identifiable within the Ramsey County coverage are included."

URL: http://www.datafinder.org/metadata/rams_water.htm

The Metropolitan Council's 2000 Water Features layer: "It generally includes lakes larger than 3 acres [1.2 hectares] and rivers wider than 200 feet [61.0 meters]. It may also include some smaller open water features."

URL: http://www.datafinder.org/metadata/hydro_luse2000.htm

5. GIS Approach

The GIS approach involves using the water layer to clip the study site polygons to end up with net land area.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon)
2. Water layer (polygon)
3. **ET GeoWizards** tool (available for free download at <http://www.ian-ko.com>)
4. **XTools** extension (available from the Downloads section of the ESRI website)

Determine Net Land Area (without water) for each Site:

1. Add the site layer and water layer to your Map Document.
2. Using the ET GeoWizards tool, remove any areas of water from the study sites (follow instructions included with the software for installation).
 - a. Open ET GeoWizards
 - b. Under the "Geoprocessing" tab, select "Erase" and click on "GO"
 - c. Select your study site polygon layer as the layer to be erased
 - d. Give your output layer a name
 - e. Click on "Next"
 - f. Select your water polygon layer as the layer to erase with
 - g. Select either Dense or Normal data type (Dense works better for polygons with many vertices)
 - h. Click on "Finish"
 - i. The new layer will be added to the Map Document
3. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select your new study site polygon layer
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit "OK"
4. New fields called "Area" and "Hectares" will be created in the attribute table of your site polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

2.2 Gross Area (including water)

1. Basic Concept

Land area is one of the most basic measurements. Area, including water, is a very gross measure that is appropriate for places without coastlines, lakes, or similar water features. However, because the Twin Cities has much water this is not used in these protocols.

2. Basic Formula

Gross Area (including water) = Area within defined geography.

3. Detailed Formula

Same as above.

4. Comments and Explanations

Includes water, areas not in parcels, basically everything.

5. GIS Approach

This is a plain vanilla land area calculation.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon)
2. **XTools** extension (available from the Downloads section of the ESRI website)

Calculate Land Area for each Site:

1. Add the site layer to your Map Document.
2. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select your new study site polygon layer
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit "OK"
3. New fields called "Area" and "Hectares" will be created in the attribute table of your site polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

2.3 Creating a Focus Area Sampling Grid and Sampling Extreme Areas (followed by randomly sampling addresses)

1. Basic Concept

This procedure identifies potential focus areas for the study and obtains a random sample of the most extreme areas, a strategy we used to guarantee environmental diversity.

This protocol is slightly different to others as it focuses on a **procedure** rather than a formula or a definition.

2. Basic Procedure

This procedure:

- Places a 805*805 meter grid over the entire study area.
 - There were a total of 780 of these. In future, we would eliminate all grid cells on the edge of the study geography unless identical data are available outside of it.
- Finds those grid cells with more than 18.75% (30 acres if there is no water) of their parcel land area in residential uses.
 - There were a total of 388 of these.

- Calculates the population per hectare (without water) for each cell, with population in blocks cut by the edge of a cell apportioned according to the land area on either side of the boundary (e.g. if 40% of the land area is in the cell, it gets 40% of the block's population).
 - See Chapter 3 for instructions on calculating population per hectare (without water).
- Calculates the Median Block Size for blocks with a centroid within the cell (using the modified census layer from TLG and Metro GIS—for description, see Chapter 1). Block centroids are used so that each block is counted as a whole and each block is allocated to only one grid cell.
 - See Chapter 6 for instructions on calculating Median Block Size.
- Arranges grid cells into a 3*3 matrix of low (up to 5 persons per acre/12.4 per hectare), medium, and high (over 10 persons per acre/24.7 per hectare) population density and small (under 5 acres/2.0 hectares), medium, and large (over 8 acres/3.2 hectares) blocks. These cut-off points reflect the character of the study area and some of the literature on population density where 10 persons per acre (the cut-off for “high” density, was the lowest cutoff we could justify in terms of walkable areas—see Frank and Pivo (1994, 46), Hess et al (1999, 1).
- Eliminates grids cells with fewer than 200 people.
- Randomly selects nine grid cells to study from the four extreme cells of this matrix.
- Checks that none of the cells will be undergoing large scale redevelopment during the study period.
 - In the case of the Twin Cities Walking Study we checked with all the relevant planning departments and two cells were each going to have hundreds of units constructed during the period of the study (causing disruption to current residents and changing the residential density and street pattern over the course of the year). We excluded these areas and resampled.

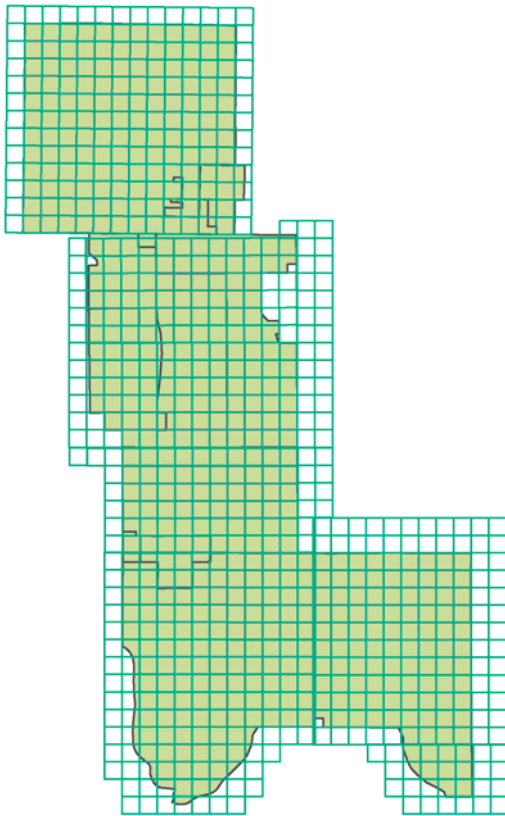
3. Detailed Procedure

As above.

4. Comments and Explanations

Some steps require additional explanation.

In placing a 805*805 meter grid over the study area, we adjusted it to fit the arterial grid so that for many of the grid cells the boundaries are roads. The logic behind this is explained in chapter 1 but was to do with simplifying some measurements. However, the actual arterial grid was offset so our sampling grid needed to be broken and manipulated a little. The diagram below shows these offsets. There were some minor overlaps and gaps, but quite minor.



Study area showing 805*805 meter grid with offsets.

These grid cells were used for sampling the participants in the study. The basic procedure includes:

- Creating an address list of all residential parcels. As there is no land use code in the Ramsey County assessor's data for mixed use, we simply included parcels matching the land use codes in the type R (residential) and M (multifamily) as found in LUC.DBF on [\\Environment\GISdata\Ramsey County\Ramsey\CAMA\ParcelDataLookup](#)] The specific parcel data base did not include separate addresses for properties with multiple units under one ownership—typically rental units. The parcels could be identified through and use type M (multifamily) and associated land use codes (401,402,403,404) In this case we purchased more accurate address lists from a private vendor.
- The revised address list for each focus area was then placed in a column in an Excel spreadsheet. The random number generating function in Excel was used to generate random numbers in the adjacent column. The two columns were then sorted and the first 20 addresses (or whatever number was needed at that time) were selected.
- Because we deliberately spread the individual level measures over 8 months, so that we were not measuring in winter and so that people from each area were being measured in spring through fall, we did multiple random selections for each phase without replacing those who had been participants (or in some cases we had promised not to contact. However, it would be equally appropriate to do one random sample at the beginning, and just move down the list as more people were needed.

5. GIS Approach

For density and block size measures, see other chapters referenced above. An ArcGIS tool, Fishnet, was used to create a shapefile of grid squares in an appropriate projection.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. A layer containing the maximum extent for analysis
2. **Create Fishnet tool (available from ESRI's ArcScripts website)**

Create the grid cell shapefile:

1. Ensure that the data view is using the desired units for measurement by checking the lower right corner of the status bar at the bottom of ArcMap.
2. Move the mouse to the lower left corner of the area for which grid cells will be created. Note the coordinates.
3. Measure the approximate horizontal and vertical distances that need to be covered by the grid and divide each distance by the intended size of each grid cell. This will yield the number of rows and columns needed in the grid.
4. Click the Create Fishnet button that was added to the toolbar during the installation of the tool.
5. Enter the X-Y coordinates of the lower left corner recorded above.
6. Enter the number of rows and columns estimated above.
7. Enter the height and width of each grid cell
8. Choose a location and name for the output shapefile
9. Click the Edit button to select the coordinate system of the output shapefile.
10. Make sure it is set to product Polygons and click OK.

2.4 Measurement Geography Type 1: Grid Cell

1. Basic Concept

This measurement geography divides an area into equal square cells for sampling and measurement. These protocols use three scales of grid cell: a focus area, a context area, and a 100m grid cell. The logic behind the first two is described in Chapter 1 and they are primarily used to create the sample frame for the study and to guide data collection.

The small, 100*100m grid cells are used in measurement where data are only available in aggregated form or where measures require grid cells for other reasons described in the protocols for those measures (e.g. the land use dissimilarity index).

2. Basic Definition

The focus area is an area 0.5 by 0.5 miles/805*805 meters used as basic measure for sampling.

The context area is an area 1.0*1.0 miles/1609*1609 meters that buffers each focus area by 0.25 miles/402 meters on all sides.

3. Detailed Formula

Focus area = Area 0.5 by 0.5 miles/805*805 meters used as basic measure for sampling. The basic focus area grid ignores water bodies but these are generally excluded from land area calculations.

Context area = Area 1.0*1.0 miles 1609*1609 meters that buffers each focus area by 0.25 miles/402 meters on all sides. The basic context area grid ignores water bodies but these are generally excluded from land area calculations. Used to collect data so that there can be a 0.25 mile straight line buffer (at least) measured around all participants.

4. Comments and Explanations

None.

5. GIS Approach

The GIS approach is to use the Create Fishnet add-on for ArcGIS to create grid cells for one study site. Convert the grid cell shapefile to graphics and copy the graphics to each study site, aligning them as well as possible with each study site. Convert all the graphics into a new shapefile and assign the correct study site ID to each group of grid cells.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. A layer containing the maximum extent for analysis
2. **XTools** extension (available from the Downloads section of the ESRI website)
3. **Create Fishnet tool (available from ESRI's ArcScripts website)**

Create the grid cell shapefile (this procedure assumes you are creating grid cells for a 1600m square study site):

1. Ensure that the data view is using meters by checking the lower right corner of the status bar at the bottom of ArcMap.
2. Move the mouse to the lower left corner of the study site for which grid cells will be created. Note the coordinates. Click the Create Fishnet button that was added to the toolbar during the installation of the tool.
3. Enter the X-Y coordinates of the lower left corner recorded above.
4. Enter 16 for the number of rows and columns.
5. Enter 100 for the height and width of each grid cell
6. Choose a location and name for the output shapefile
7. Click the Edit button to select the coordinate system of the output shapefile.
8. Make sure it is set to product Polygons and click OK.

Save grid cells to graphics and duplicate:

1. Right click on the new grid cell layer in the Table of Contents and choose *Convert Features to Graphics*
2. Select the graphic grid cells (all 256 of them) so they are highlighted
3. Right click and choose *Group* to combine the cells into one selectable graphic
4. Right click to Copy and Paste the graphic to other study sites
5. Align the graphics to each study site
6. Select all the graphics, right click and choose *Ungroup*

Create grid cell shapefile:

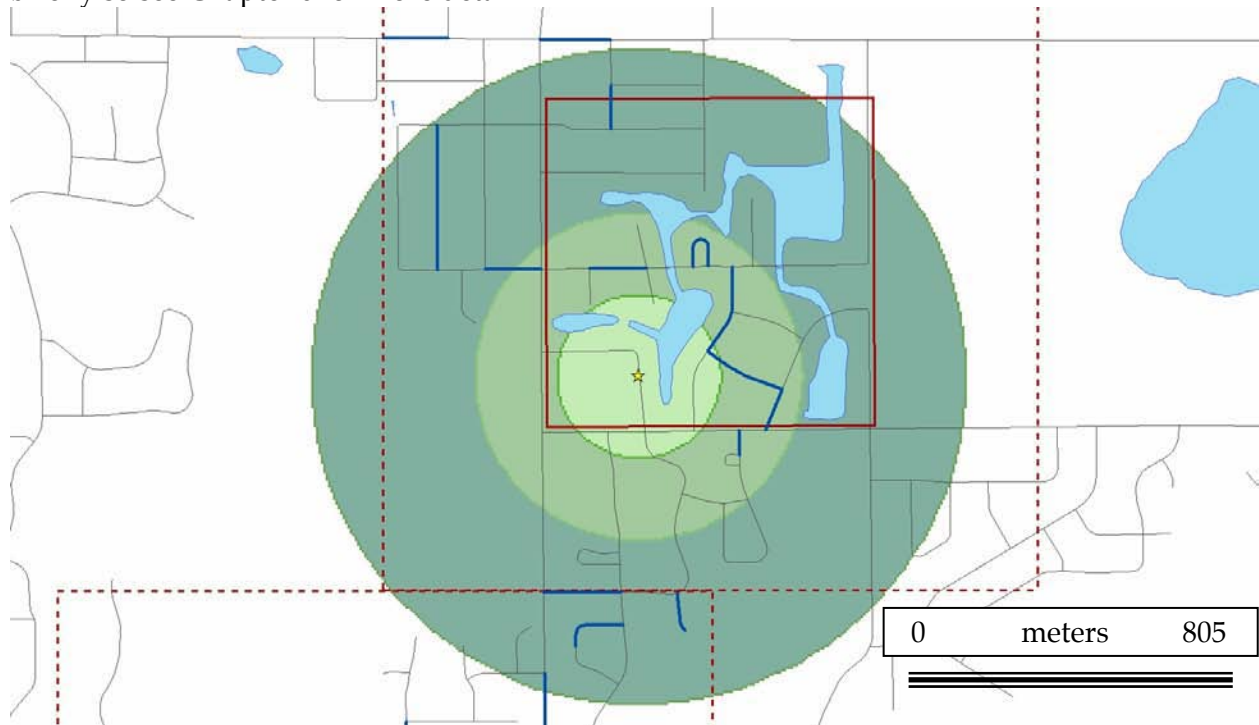
1. Open the XTools menu in the toolbar and choose *Feature Conversions* → *Convert Graphics to Shapes*
2. Select the polygon features and hit OK
3. The new shapefile will be added to the ArcMap document

2.5 Measurement Geography Type 2: Straight Line or Airline Buffer

1. Basic Concept

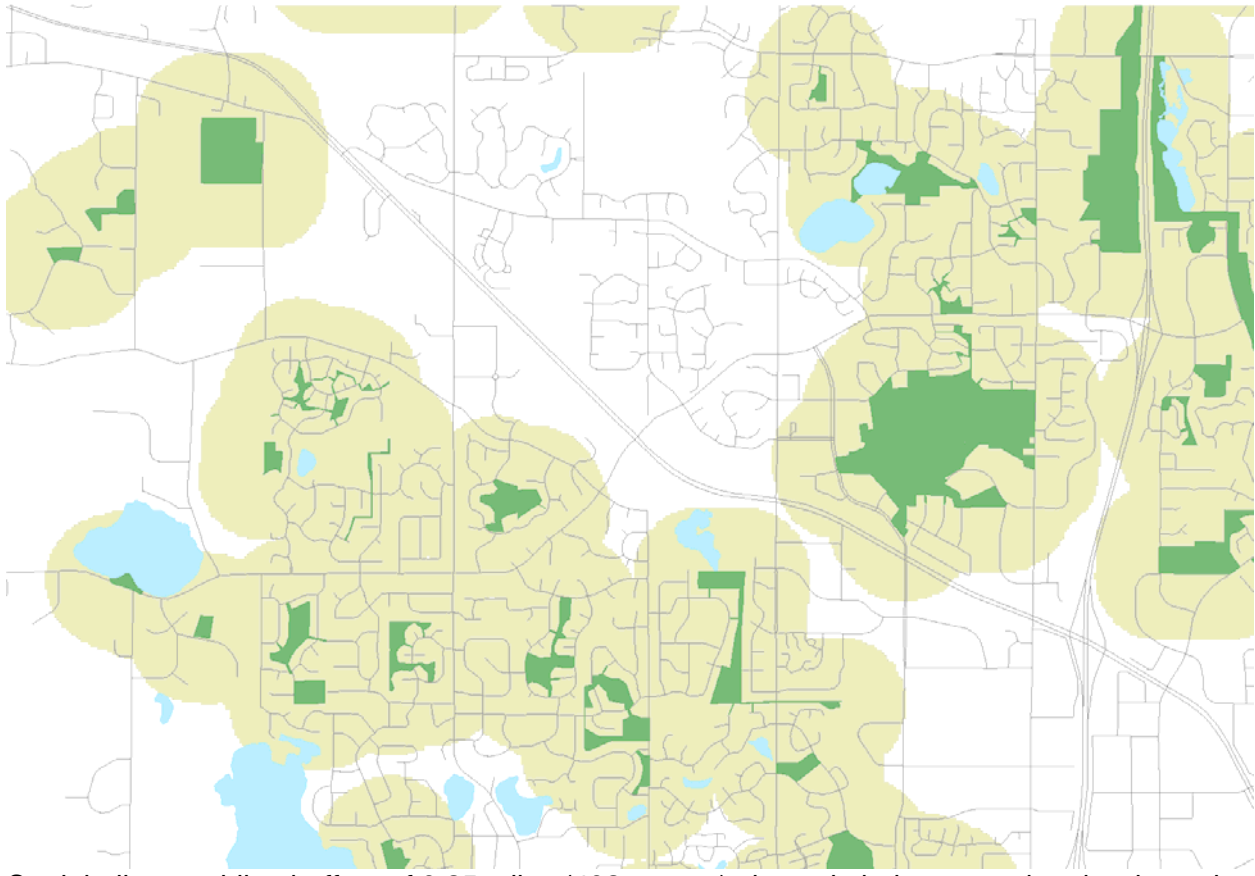
This measurement places a buffer around a point or polygon and the radius of the buffer is equal at all points. This is useful in measuring the general context of a person. While the street network buffer (see next protocol) focuses on street distances, pedestrians do not always walk on streets and in some locations, the straight line or airline buffer may well capture parts of the environment accessible to pedestrians through parks, parking lots, trails, and informal paths.

It should be noted that we also use very small buffers in defining intersections, largely to eliminate classification errors from slightly offset intersections. This is complex to describe briefly so see Chapter 6 for more detail.



Straight line or airline buffers of three different radii (in this case 0.125, 0.25, and 0.5 miles or 201, 402, and 805 meters) around a hypothetical individual.

Buffers can also be created around polygons such as parks. The following diagram shows straight line buffers of 0.25 miles/402 meters around parks in a suburban area of the Twin Cities. In this case buffers around several parks have been merged to show areas within 0.25 miles/402 meters of any park (shaded) and beyond that distance (white). These maps are from separate work on park access for the Trust for Public Land.



Straight line or airline buffers of 0.25 miles (402 meters) shown in beige around parks shown in green. Areas beyond that distance are in white.

2. Basic Definition

A straight line buffer is an area within “X” meters straight line distance of a point (or a polygon).

3. Detailed Definition

A straight line buffer is an area within “X” meters straight line distance of a point (or a polygon). In the case of this study with a sample based on residential environments, the straight line distance is from a participant's home. More specifically, it is the straight line distance from the residence on the participant's parcel, located visually from aerial photos.

4. Comments and Explanations

This is a straightforward process in ArcGIS 8.3, using the Buffer Wizard. The software lets you choose whether to keep the buffers distinct (one per feature) or merge them into one big feature. For the parks analysis shown in the image above, the buffers could be merged together, as it was not necessary to retain a relationship between an individual park and its buffer. For the Twin Cities Walking Study, each buffer was tied to a participant's home location, so the buffers had to remain distinct.

Picking the starting point was a bit more time consuming in this process as we only partially automated it but rather checked the geocoding from the parcel data base. The geocoding process works with the length of the street segment and the address range associated with it,

and just places points along the length of the line proportionally using the address and the known range. In order to have the points in the correct place we used the parcel data (to match exact addresses) and the orthophotos (to find the building locations) and manually shifted points to reflect the actual location of participants. In a larger study, we would automate this step to use the centroid of the parcel of residence. The manual placement of points makes the most difference in larger or longer lots where the centroid may be some distance from the actual house, affecting small buffers in particular.



In the picture to the left you can see the parcel centroid marked with a green X, while the house sits at the back of the parcel with a long driveway out to the road. In this picture the distance from the point on the house out to the road is just over 400m.

Buffering can be a large task. For instance, for census-based measures it is important to intersect straight line buffers and census blocks, that is to cut census blocks into sections that overlap with each individual buffer. This is a large processing task that requires two stages. First is the normal intersect between a set of buffers and the census blocks. Then, because of the buffers of participants in a limited geographical area tend to overlap, the resulting file has to be run through the Dissolve procedure in the GeoProcessing Wizard. After intersecting census blocks with many overlapping buffers, each buffer gets split into many pieces. By dissolving this layer by **both** the unique ID of the buffer and the unique census block ID, the file is put back together into all the unique combinations of the two attributes. The result is the equivalent of simply doing a spatial intersect with non-overlapping buffers. The first step results in extremely large files, for example intersecting 715 1600m buffers and the approximately 6500 census blocks they touch took nearly a half hour and generated a file containing 2.65 million records. In order to avoid the computer crashing, this had to be broken up into six chunks of approximately half a million records each because the dissolve tool would crash trying to operate on more records than that. When all six pieces were done, the append tool was used to merge them back together—the final file contains 156,000+ records (i.e. census blocks and parts of census blocks)

5. GIS Approach

Use the Buffer Wizard in ArcGIS to create one or more buffers a specified distance or distances from a selected set of features.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Participant location layer (point) with unique ID field

2. Census block layer (polygon) with field containing population

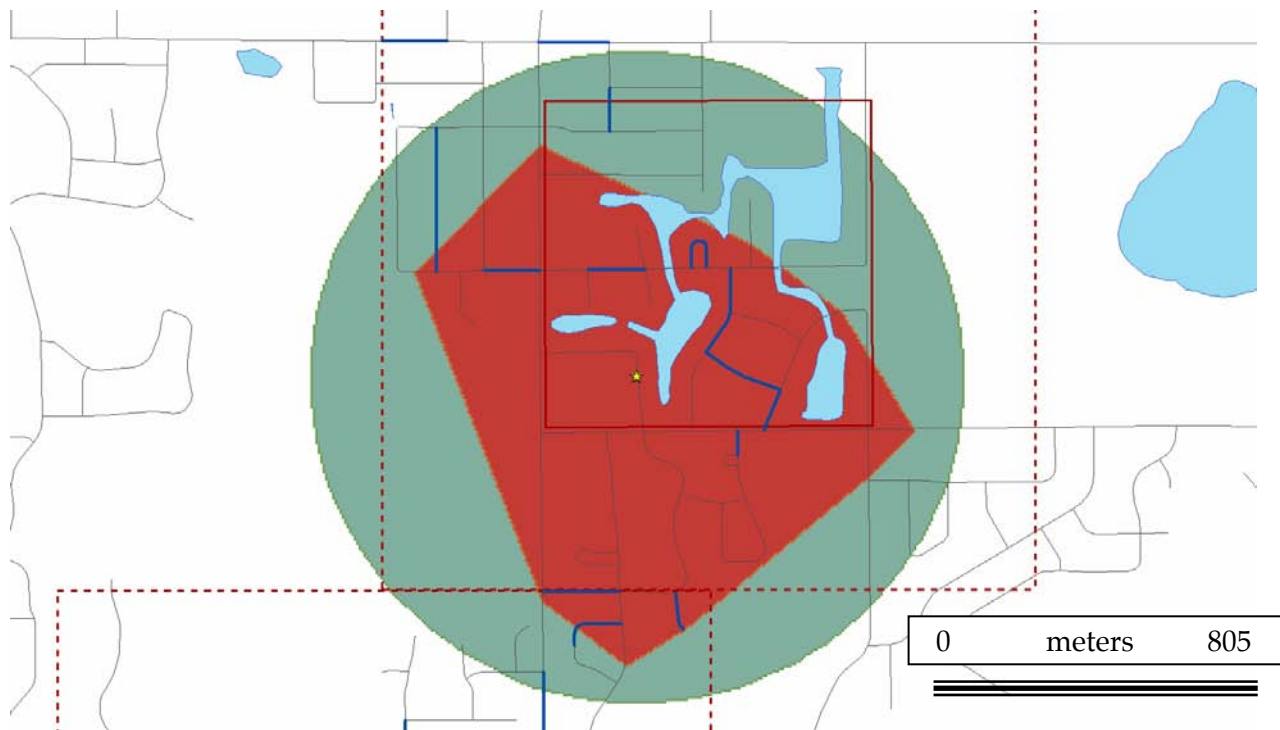
Create Participant buffers:

1. Under the Tools dropdown menu, select "Buffer wizard".
2. In the Buffer Wizard window, under "The features of a layer" select your participant locations layer and click on *Next*
3. Click "At a specified distance" and enter XX (your desired distance)
4. After "Distance units are:" select *meters*
5. Click *Next*
6. After "Dissolve barriers between" select *No*
7. Give the layer a name and save as a new layer
8. Click *Finish*

2.6 Measurement Geography Type 3: Network or Street Distance Buffer

1. Basic Concept

This kind of buffer uses the street network as the organizing geography. A buffer of 400 meters would start by finding all points on the street network that are 400 meters from the starting point and then joining the dots. Its basic idea is that people use the street network to move about and something that is 400 meters as the straight line may be several times that far in an area with a winding or discontinuous street pattern. The illustration below shows this for a 0.5 mile (805 meter) buffer around the same point as in the previous diagram. The network buffer is significantly smaller than the straight line buffer.



Straight line versus network buffers for a radius of 0.5 miles or 805 meters around a hypothetical individual.

It is important to note that the network buffer is not always a better than a straight line buffer as a measure of accessible areas. In some locations there may be many pedestrian paths and cuts—though that are not streets. This means that it may be useful to test both kinds of buffers.

2. Basic Definition

A network buffer is an area within “X” meters street distance of a point (or a polygon).

3. Detailed Definition

A network buffer is an area within “X” meters street distance of a point (or a polygon) In the case of this study with a sample based on residential environments, the street network distance is from a participant's home. More specifically, it is the network distance from the house or building on the participant's parcel, where the building is located visually from aerial photos. Where, due to the lack of cross streets these buffers are zero or very small, we created a work around that created a minimum buffer size of 12,000 square meters.

4. Comments and Explanations

This is a little trickier to do in GIS than the straight line buffer. Currently Network Analyst, the tool that creates network buffers, has not been released for ArcGIS so this must be done in ArcView 3.3 and then re-imported into ArcGIS.

In addition, there are some added complications particularly for smaller buffers in street patterns dominated by culs-de-sac. Network Analyst works by finding points on the network—in this case the street—a specified distance along the network from the starting point. It then joins these points into some kind of polygon. For 200 meter buffers in areas without many cross streets, 200 meters might just result in a long, skinny line up and down a single street. This results in a buffer that does not intersect with land use, street trees, or other items outside of the road right of way. We could not find any direction for this in the literature so created a minimum buffer for those of 15 meters on each side of the road center line for 185 (200 minus 15) meters each way or approximately 12,000 meters squared or 1.2 ha. Overall, approximately 60 buffers, or approximately 8 percent of buffers, received this minimum size. We in fact came to this in two steps—we first ran minimum buffers on zero or almost zero network buffers, but these minimums ended out to be bigger than some of the standard network buffers, given slight curves in the road and the odd intersection, up to 12,000 square meters. So then we expanded the number of minimum buffers to all those under 12,000 square meters. This also involved moving starting points out to the right of way, where they were close (in two cases they were far and were not moved).

We end up with 656 [check] unmodified features; 57 [check] that were edited by moving the points out to the road and running them through Network Analyst, taking the resulting road features, and buffering them by 15m; and 2 features set to have 200m network buffers of 0 square meters.

5. GIS Approach

Use the Network Analyst extension for ArcView 3.3 to determine a service area around a set of point features. This requires lines features such as roads or trails which will become the network used to calculate all possible routes of a specified distance from the selected points.

6. GIS Steps

The following procedures were completed using ArcView 3.3.

To complete this protocol you will need:

1. Roads layer (polyline)
2. A set of features from which to buffer—in this example, participant locations (point)
3. The Network Analyst extension for ArcView

Prepare the view and data:

1. Add the roads theme and the participant theme to a new view
2. Go to the *View* menu and choose *Properties*
3. Set the map units and distance units appropriate for the coordinate system of the layers
4. In the view, select the participant theme, open the *Theme* menu, and select *Table...*
5. Go to the *Table* menu and select *Start Editing*
6. Go to the *Edit* menu and select *Add Field*
7. In the Field Definition window, name the field REPORTCOST
8. Choose the field type *Number*, then click OK
9. In the theme's table, click on the name of the newly added field (it should turn dark gray)
10. Go to the *Field* menu and choose *Calculate...*
11. Enter the buffer distance and click OK

Calculate network buffers:

1. In the view, highlight the roads theme
2. Go to the *File* menu and choose *Extensions*
3. Scroll to Network Analyst, check the box, and click OK. There should now be a *Network* menu at the top of the ArcView window
4. Go to the *Network* menu and choose *Find Service Area*
5. Check the radio button for *Travel from site*
6. Click the *Load Sites* button
7. When asked to choose a theme, select the participant locations theme and click OK
8. The Find Service Area window will now be titled Sarea1 and Snet1. Click the button in the upper right with a picture of a grid and a black arrow on it.
9. When the processing finishes, the polygon theme Sarea1 will contain the network buffers
10. To export the features to a fresh shapefile, click on the Sarea1 theme, go to the *Theme* menu, and choose *Convert to shapefile*
11. Choose a location and name for the output file and click OK.

2.7 Measurement Geography Type 4: Straight Line or Airline Distance to Nearest Feature

1. Basic Concept

If people walk at least partly in order to reach an important destination, such as a park or a supermarket, then the distance to the closest example of a specific kind of destination is an important issue.

2. Basic Definition

The straight line distance to the nearest feature is the distance to the closest X.

3. Detailed Definition

The straight line distance to the nearest feature is the distance to the closest X where X is a type of destination.

4. Comments and Explanations

This measurement uses an ArcView extension called Nearest Features. It was developed by Jeff Jenness, a wildlife biologist, and can be downloaded here:

http://www.jennessent.com/arcview/nearest_features.htm

It is also possible to do this in ArcGIS 9, but we have not yet used that tool.

For determining the shortest distance from a participant to a business, the distance is between the two points. When determining the nearest polygon feature, for example a park, the distance is calculated between the participant and the closest vertex. Vertices are more useful representations of access than centroids, particularly if the polygon feature (e.g., a park) is very large or oddly shaped. In this case, the centroid may be located far from the nearest road.

5. GIS Approach

This calculation simply involves determining the straight line distance between an origin and the closest of the possible destinations of the desired type (businesses, parks, etc). For non-point destinations, this measurement requires a decision about what part of the feature to call the endpoint of the shortest distance line—the centroid, vertex, or closest edge.

6. GIS Steps

The following procedures were completed using ArcView 3.3.

To complete this protocol you will need:

1. Roads layer (polyline)
2. A set of origin features—in this example, participant locations (point)
3. A set of destination features (point)
4. The Nearest Features extension for ArcView

Prepare the view and data:

1. Add the roads theme and the origin/destination themes to a new view
2. Go to the *View* menu and choose *Properties*
3. Set the map units and distance units appropriate for the coordinate system of the layers
4. Go to the *File* menu and choose *Extensions*
5. Find the Nearest Features extension and check the box to turn it on
6. Click *OK*

Calculate distance to nearest feature

1. Click on the Nearest Features button in the toolbar
2. In the first dialog box, select the theme of origin features and the field in its table that contains a unique ID
3. Click *OK*
4. In the next dialog box, select one or more destination themes (if you want to calculate the distance to nearest feature for more than one kind of feature at a time), and for each theme choose a field containing a unique ID
5. Click *Add* for each combination of feature and unique ID
6. Click *OK* when finished
7. In the next dialog box, enter the number of nearest features you want to find (1 = nearest feature, 2 = nearest and second-nearest features, etc) and check the boxes for Comparison Feature ID and Distance to Centroid
8. Click *OK*
9. In the final dialog box, you may choose to draw lines connecting each origin and its nearest destination (this will increase processing time)
10. Click *OK* to begin the processing

The output will be a table containing the unique ID of each origin feature, the unique ID of the nearest destination feature, and the distance between them in the chosen units of the view.

2.8 Measurement Geography Type 5: Network or Street Distance to Nearest Feature

1. Basic Concept

As with the straight line distance, network or street distance is important as a measure of accessibility of destinations. As stated in the previous protocol, if people walk at least partly in order to reach an important destination, such as a park or a supermarket, then the distance to the closest example of a specific kind of destination is an important issue.

However, the straight line distance may not be a realistic measure of the actual distance to the nearest feature as people typically walk along streets and therefore the street distance is a more accurate measure. It is important to note that it is not always better as in some areas there may be many pedestrian paths and cuts-through that are not streets. This means that it may be useful to test both kinds of distance measures.

2. Basic Definition

The street distance to the nearest feature is the distance to the closest X.

3. Detailed Formula

The network distance to the nearest feature is the distance to the closest X where X is a type of destination and the closest X is the closest X in terms of street distance. There may well be closer destinations of this type in straight line terms but barriers or street patterns make them further along the network.

4. Comments and Explanations

This is also done using Network Analyst in ArcView 3.3 (see network buffers above) using a function called Find Closest Facility. You can specify a point layer to use as your “facilities” and then also a point to serve as your origin. It will then take the road network and calculate the shortest path to a “facility” (and it can do this using travel costs as well if, for instance, certain types of roads were considered more or less easy to use).

The basic function only works for a limited number of base points (12). In our case we had 715 valid participant addresses so needed to use an ArcView extension called Multiple Closest Facilities. It can be downloaded from the ESRI website at <http://arcscripts.esri.com/details.asp?dbid=13125>. For points that do not fall on the network, there is a dialog box when using this extension that allows the user to decide how far away from the network to search for points to use in the processing. Points outside that distance will not be used.

5. GIS Approach

The approach for this measure is to load a set of origins and destinations. Then use the Find Closest Facility feature in Network Analyst or the Multiple Closest Facilities extension to calculate the network distance from each origin to the nearest destination.

6. GIS Steps

The following procedures were completed using ArcView 3.3.

To complete this protocol you will need:

1. Roads layer (polyline)
2. A set of origin features—in this example, participant locations (point)

3. A set of destination features—in this example, employment locations (point)
4. The Network Analyst extension for ArcView
5. The Multiple Closest Facilities extension for ArcView

Calculate network distance to nearest facility

1. Start a new ArcView project and create a blank View
 - a. Open the *View* menu and choose *Add Theme*
 - b. Add the roads, origins, and destinations layers to the View
 - c. Open the *View* menu and choose *Properties*
 - d. Make sure the map units (meters, feet, etc.) match the units of the data layers
 - e. Open the *File* menu and choose *Extensions*
 - f. Check the box next to the *Multiple Closest Facilities* extension and click OK
2. Open the *Network Tools* menu that has been added and choose *Multiple closest facilities*
3. In the dialog box that appears, select the origins layer in the *From* dropdown box
4. Select the unique ID of the origins layer in the *From ID field* dropdown box
5. In the *To* dropdown box, select the destinations layer
6. Choose the unique ID of the destinations layer in the *To ID field* dropdown box
7. In the *Network* dropdown box, select the roads layer
8. For *Facilities to find*, enter 1
9. Set the *Cutoff Distance* to 0
10. The *Search Tolerance* is a distance in the current map units that Network Analyst will search away from the road features to find points. Make this number large enough so the process will not miss any of the origin points
11. Click *Travel to facility*
12. Check the box for *Create Join Table*
13. Hit *Process*

When the process ends, the extension will add a new polyline feature to the View consisting of the network segments that trace the shortest path from each origin to its nearest destination. The table of the new layer contains an Origin field with the unique ID of the origin layer, a Destin field with the unique ID of the closest destination feature, and a Length field with the distance in the current map units between the origin and the closest destination.

2.9 Measurement Geography Type 6: Parcel of Residence

1. Basic Concept

Recent work by Anne Vernez Moudon and her research team has found correlations between features of the parcel of residence and walking, more of a correlation than some larger geographies—in her case 1km and 3km buffers. This may be due to features of the parcel of residence being a proxy for non-environmental features such as levels of car ownership or due to the lack of intermediate scales in her analysis. We are using parcel of residence to check some of these variables.

2. Basic Definition

The parcel in which a participant resides.

3. Detailed Formula

As above.

4. Comments and Explanations

None.

5. GIS Approach

This merely involves selecting the parcel of residence.

6. GIS Steps

Steps are in other protocols.

3. DENSITY

Chapter by: Ann Forsyth (drafting, conceptual issues and formulae, some comments and GIS approach text) and Joel Koepf (GIS Steps and the rest of the comments and GIS approach text).

The only change between version 2.1 and Version 2.0 was some additional detail in protocol 3.3. For version 2.3 an error was corrected in Protocol 3.4 (it does exclude water).

Background

Density is the number of units (people, trees, housing units etc) in a given area. Some researchers propose that density is primarily a proxy for other variables that actually cause walking and others propose it is more directly causal. Those on the proxy side argue that it is highly correlated with older neighborhoods with gridded streets, mixed use, low income people, etc. For those seeing a more direct link, density provides a critical mass of people and places, a physical sense of community, auto congestion, and makes transit viable so people walk to transit (for reviews see Ewing 1994; Steiner 1994; Cervero and Kockleman 1997; Handy 2003; Audirac 1999).

There are many measures of density depending on what the density is of (residents, employees, buildings) and the base land area (a parcel, a whole neighborhood) (Forsyth 2003, see Figure 3.1 below). A single home may be part of different measurement areas that give it different overall densities depending on the scale of the measures (see Figure 3.2 below). Note, the figures use a different terminology from the protocols, largely because the protocols are independent of size of base area.

Not all density measures are reported in this section—for example, Chapter 4, on pedestrian infrastructure, contains a number of density measures such as street tree density.

Figure 3.1 Selected Residential Density Definitions

Note: this uses a different terminology from the protocols, largely because the protocols are independent of size of base area

Source: Forsyth 2003; Reprinted from Forsyth 2004a

Parcel or Site Density: dwelling units (DUs) or residential population (RP) divided by total site/parcel area (all uses). This is often used by developers. It is easy to calculate with GIS but also fairly simple by hand if there is only one parcel. However, since parcel boundaries are not always visible on the ground this form of density can be hard to calculate from physical observations.

Block Density: DUs or RP divided by block area measured to the curb. This is relatively easy to measure from aerial photos and census data, and reflects a unit that is part of the experience of place, the block. However, if the block is not surrounded by roads, for example where it abuts open space, the boundaries can be less clear.

Net Neighborhood Residential Dwelling/Population Density: DU or RP divided by total land area devoted to residential facilities. This is a calculation that involves defining both a neighborhood and residential land within that neighborhood. Care must be taken in assigning land to residential uses rather than, say, recreation--the key is to find equivalent elements in different residential designs.

Net Neighborhood Density (NND): DU or RP divided by the neighborhood area with the base land area calculated to exclude city-wide uses in the neighborhood. Included in the neighborhood land area are residential land, streets, and neighborhood type uses—schools, parks, churches/synagogues/temples etc. and neighborhood shopping. Excluded are city-wide businesses, public uses, high schools and colleges, major arterials, major regional parks, and vacant and unusable land. These exclusions can be difficult to calculate (adapted from Alexander 1993).

Gross Neighborhood Density (GND)/Gross Census Tract Density (GCTD): DU or RP divided by the total neighborhood area. This is easy to calculate although it may be skewed by regional uses such as regional parks. The Gross Census Tract Density is particularly useful as it is available across the United States from census information and does not rely on local data.

City Density (CD): DU or RP divided by the entire developed area of the city or town. In built out local government areas this is in practical terms the entire city. On the urban edge, it includes only developed land, a more complex calculation (adapted from Alexander 1993). This is also a gross density.

Metropolitan Density (MD): DU or RP for US Census Metropolitan Statistical Area divided by total land area. This calculation includes undeveloped areas which will lower the overall figures, but is nationally comparable. The US Census prepares such density figures. This is also a gross density.

Figure 3.2 Comparison of Residential Density Measures for the Same Location

Source: Forsyth 2003

Site density	10 DUs per acre/25 per hectare
Block density	8 DUs per acre/20 per hectare
Net neighborhood residential density	10 DUs per acre/25 per hectare
Net neighborhood density	6 DUs per acre/15 per hectare
Gross neighborhood density	5 DUs per acre/12 per hectare
City density	4 DUs per acre/10 per hectare
Metropolitan density	3 DUs per acre/7 per hectare

3.1 Raw Population per Unit Land Area

1. Basic Concept

This is the most basic gross measure of population density, defined as the population of those who reside in housing in the area. It should be noted that this measure is independent of scale and could be used to measure the population per hectare of a small grid cell or an entire metropolis (and therefore would have different names e.g. raw grid cell density, raw metropolitan density).

Sources that have used this measure, typically at a neighborhood or census tract level, and that will be more fully discussed in the next draft of this manual include Frank and Pivo (1994, 46), Hess et al (1999, 1), Schimek (1996, 121), and Dunphy and Fisher (1996, 91).

Because the Twin Cities has a great many lakes, we generally used the next protocol, which excludes water.

2. Basic Formula

Raw Population per Unit Land Area = Persons in housing units per unit area with no exclusions.

3. Detailed Formula

Raw Population per Unit Land Area = Persons in housing units as measured in the US Census per unit area with no exclusions.

4. Comments and Explanations

Where census blocks are cut by the end of the measurement geography, the population is apportioned according to the percentage of land area falling inside and outside the line.

5. GIS Approach

Use ArcGIS to intersect study sites with census blocks. Retain the original area of each census block and then use XTools to update the areas after performing the intersect procedure. Find the proportion of new area to original area and multiply the census population figure by that same proportion. Finally, divide this apportioned population figure by the updated area.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Parcel layer (polygon)
3. Census block layer (polygon) with field containing population
4. **XTools** extension (available from the Downloads section of the ESRI website)

Determine the apportioned census population figure for each site:

1. Add the site layer and census block layer to your Map Document.
2. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the census block layer
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
3. New fields called "Area" and "Hectares" will be created in the attribute table of your new census block polygon layer with the areas of each polygon calculated in the units you chose (Area) and in Hectares (Hectares).
4. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your census blocks as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
5. Open the Attribute Table of the census block layer created in the previous step.
 - a. Click on *Options* and choose *Add Field*
 - b. Name the field OrigHect and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the OrigHect field
 - d. Choose *Calculate Values*
 - e. In the Field Calculator, double click Hectares and click OK.
 - f. You have now copied the values from Hectares to OrigHect

6. From the XTools menu, select “Table Operations” and then “Calculate Area, Perimeter, Length, Acres, and Hectares” (follow instructions included with the extension for XTools installation).
 - a. Under “Select layer to measure,” select the clipped census block layer created in step 4 above
 - b. Under “Desired output units,” choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
7. This will overwrite the values in the Hectares field with the new correct values (since the shapes have been clipped to the extent of the study site layer), yet the original number of hectares is preserved in the OrigHect field.
8. To perform the population apportionment, open the Attribute Table of the clipped census block layer again.
 - a. Click on *Options* and choose *Add Field*
 - b. Name the field PopSplit and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the PopSplit field
 - d. Choose *Calculate Values*
 - e. In the Field Calculator, double click Hectares, then hit the / button, then double click OrigHect, hit the * button, and finally double click the name of your Population field
 - f. Hit OK
9. The result is a field called PopSplit that contains the same proportion of the original census population figure as the proportion of the clipped census block area to the original area.

Perform final calculation

1. In the Attribute Table of the clipped census block layer, right click on the name of the site ID field and choose Summarize
 - a. In the box beneath *Choose one or more summary statistics...*, click the + next to PopSplit
 - b. Check the box next to Sum
 - c. Choose a name and location for the output summary table
 - d. Click OK
2. Join this summary table into the study site layer table using the ID field
 - a. Add a new field of type double called PopPerHect
 - b. Right click on this new field and choose Calculate Values
 - c. In the Field Calculator, double click on the PopSplit field, then click the / button, and finally double click on the Hectares field from the study site layer.
 - d. Hit OK

The PopPerHect field now contains the total apportioned population per hectare for each study site.

3.2 Population per Unit Land Area (without water)

1. Basic Concept

In areas with many lakes, water provides an important barrier to walking. As the Twin Cities is one such area, many of our calculations used this population density measure which is identical to the one above except that it excludes water.

2. Basic Formula

Population per Unit Land Area (without water) = Persons in housing units per unit gross area excluding water.

3. Detailed Formula

Population per Unit Land Area (without water) = Persons in housing units as measured in the US Census at the block level per unit land area excluding area of water features as measured in the Ramsey County layer.

4. Comments and Explanations

Where census blocks are cut by the end of the measurement geography, the population is apportioned according to the percentage of land area falling inside and outside the line.

5. GIS Approach

The approach to this measurement is to intersect census blocks with study sites, preserving the original area of each block and then recalculating it after the spatial intersect procedure. Calculate the apportioned population and divide it by the total area that has been recalculated after removing the area of all water features.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Parcel layer (polygon)
3. Census block layer (polygon) with field containing population
4. Water features layer (polygon)
5. **XTools** extension (available from the Downloads section of the ESRI website)

Determine the apportioned census population figure for each site:

1. Add the site layer and census block layer to your Map Document.
2. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the census block layer
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
3. New fields called "Area" and "Hectares" will be created in the attribute table of your new census block polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).
4. Open the GeoProcessing Wizard.
 - g. Choose *Intersect two layers* and click *Next*
 - h. Select your census blocks as the input layer
 - i. Select your study site layer as the overlay layer
 - j. Choose a name and location for the output layer
 - k. Click *Finish*
 - l. The new layer will be added to the Map Document
5. Open the Attribute Table of the census block layer created in the previous step.
 - e. Click on *Options* and choose *Add Field*
 - f. Name the field OrigHect and make it of type Double
 - g. Back in the Attribute Table, right click on the name of the OrigHect field
 - h. Choose *Calculate Values*
 - i. In the Field Calculator, double click Hectares and click OK.
 - j. You have now copied the values from Hectares to OrigHect
6. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).

- k. Under “Select layer to measure”, select the clipped census block layer created in step 4 above
 - l. Under “Desired output units”, choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - m. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - n. Hit OK
7. This will overwrite the values in the Hectares field with the new correct values (since the shapes have been clipped to the extent of the study site layer), yet the original number of hectares is preserved in the OrigHect field.
8. To perform the population apportionment, open the Attribute Table of the clipped census block layer again.
 - o. Click on *Options* and choose *Add Field*
 - p. Name the field PopSplit and make it of type Double
 - q. Back in the Attribute Table, right click on the name of the PopSplit field
 - r. Choose *Calculate Values*
 - s. In the Field Calculator, double click Hectares, then hit the / button, then double click OrigHect, hit the * button, and finally double click the name of your Population field
 - t. Hit OK
9. The result is a field called PopSplit that contains the same proportion of the original census population figure as the proportion of the clipped census block area to the original area.

3.3 Population per Developed Land Area (without water)

1. Basic Concept

This is a measure of resident population divided by the land area in parcels; that is, excluding rights of ways, water bodies, and land not in parcels. It has been used by some as a slightly less gross measure of population density.

Cervero and Kockelman (1997, 203) who used this measure, based it on data from a Association of Bay Area Governments database that had dominant land uses at the 1ha level.

[Note we are checking this definition in relation to Cervero and Kockelman (1996, 8) and McCann and Ewing (2003, 10). We are still considering whether to use it.]

2. Basic Formula

Population per Developed Land Area = Persons in housing units per unit land area in parcels.

3. Detailed Formula

Population per Developed Land Area = Persons in housing units as measured by the US census at block level per unit land area in parcels that is excluding rights of ways, water bodies, and land not in parcels. Where census blocks are cut by the end of the measurement geography, the population is apportioned according to the percentage of land area falling inside and outside the line.

4. Comments and Explanations

This requires access to both parcel data and census data.

Our parcel layer was modified to reflect the most detailed data with respect to water features. In Ramsey County, this was a country water features shapefile. For the other counties involved,

the best data came from the Metropolitan Council's 2000 land use shapefile (selecting the Water designation). These areas were erased from the parcel shapefile.

Our parcel data in Dakota County required two modifications at this point. Where a new(er) highway had been built, the underlying parcels had not been removed from the parcel layer. We manually removed the parcels that were within the road bed and coded those outside the road bed but within the apparent right of way as vacant. Also, another area had been platted for many roads but only one had been constructed. This road bed was isolated and removed – the rest of the rights of way (unbuilt) were left coded as Open Space.

5. GIS Approach

The parcel layer (with areas of water removed as noted above) was intersected with the site layer and the areas of the parcels recalculated to account for those that were split by the study site boundaries. Since developed land was defined as all land excluding rights of ways, water bodies, and land not in parcels, this parcel layer served as our developed land layer. Perform a spatial intersect between the developed land layer and the measurement geographies. Use XTools to update the area of the features in the resulting layer, then open its Attribute Table and summarize it based on the measurement geography ID field, calculating the sum of the Area field in the process. This will yield the total developed land area for each feature in the measurement geographies.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Land use parcel layer (polygon)
3. Census block layer (polygon) with field containing population
4. **XTools** extension (available from the Downloads section of the ESRI website)

The basic steps are:

- *Determine Net Land Area (without water) for each Site*
- *Intersect Parcels with Site Layer*
- *Calculate apportioned Census population for each Site*
- *Intersect Developed Land with Site Layer*
- *Summarize Attribute Tables of intersected Census and Developed Land layers*
- *Calculate Population per Developed Land Area*

Determine Net Land Area (without water) for each Site:

1. Follow the steps outlined in **Protocol 2.1**.

Intersect Parcels with Site Layer:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using the GeoProcessing Wizard, intersect the land use parcel layer with the new (net area) site polygon layer
 - a. Under the Tools menu, select "GeoProcessing Wizard".
 - b. Select "Intersect two layers" and click on "Next".
 - c. Under "Select the input layer to intersect:" choose your land use parcel layer.
 - d. Under "Select a polygon clip layer:" choose your site layer.
 - e. Give your file a name and hit "Finish".
 - f. The parcels will now be clipped to the study site boundaries, have areas of water removed, and be assigned the IDs associated with each study site. Note that parcels that

- exist in two or more overlapping study sites will now be represented by two or more identical (except for ID number) rows in the attribute table).
3. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select your new land use parcel layer
 - b. Under "Desired output units", choose your units (depending on the parcel size, try *Meters* or *Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit "OK"
 4. New fields called "Area" and "Hectares" will be created in the attribute table of your new land use parcel layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

Determine the apportioned census population figure for each site:

1. Add the site layer and census block layer to your Map Document.
2. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the census block layer
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles*, *Meters*, or *Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
3. New fields called "Area" and "Hectares" will be created in the attribute table of your new census block polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).
4. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your census blocks as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
5. Open the Attribute Table of the census block layer created in the previous step.
 - a. Click on *Options* and choose *Add Field*
 - b. Name the field OrigHect and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the OrigHect field
 - d. Choose *Calculate Values*
 - e. In the Field Calculator, double click Hectares and click OK.
 - f. You have now copied the values from Hectares to OrigHect
6. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the clipped census block layer created in step 4 above
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles*, *Meters*, or *Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
7. This will overwrite the values in the Hectares field with the new correct values (since the shapes have been clipped to the extent of the study site layer), yet the original number of hectares is preserved in the OrigHect field.
8. To perform the population apportionment, open the Attribute Table of the clipped census block layer again.
 - a. Click on *Options* and choose *Add Field*

- b. Name the field PopSplit and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the PopSplit field
 - d. Choose *Calculate Values*
 - e. In the Field Calculator, double click Hectares, then hit the / button, then double click OrigHect, hit the * button, and finally double click the name of your Population field
 - f. Hit OK
9. The result is a field called PopSplit that contains the same proportion of the original census population figure as the proportion of the clipped census block area to the original area.

Determine total area of developed land for each site:

1. Add the site layer and developed land layer to your Map Document.
2. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your developed land as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
3. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the layer created in the previous step
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
4. New fields called "Area" and "Hectares" will be created in the attribute table of your new parcel polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

Calculate population per developed land area:

1. For each of the two new layers (developed land and census blocks clipped to extent of the measurement geographies), do the following:
 - a. Open the layer's Attribute Table
 - b. Right-click on the name of the field containing the unique ID of the study site
 - c. Choose *Summarize*
 - d. In the box beneath *Choose one or more summary statistics...*, click the + next to Hectares
 - e. Check the box next to Sum
 - f. Choose a name and location for the output summary table
 - g. Click OK
2. Join one of the resulting summary tables to the other based on the study site ID field
3. Add a field called PopPerDevL of type double
4. Click Options and choose Calculate Values
5. In the Field Calculator, double click Sum_Popsplit, click the / button, and then double click the Sum_Hect field from the residential parcel summary table
6. Hit OK

The field PopPerDevL now contains the result of dividing the apportioned census population for a study site by the total area of developed land for the study site. The table can be joined with your study site shapefile based on the site ID, allowing you to copy the values into a new field you can create in the study site Attribute Table.

3.4 Residential Population in Residential Parcels (Residential Density) (without water)

1. Basic Concept

This density calculation reflects the kinds of densities that are talked about by developers, rather than the experience of place. That is, while people experience a whole environment—including roads and non-residential uses—developers build on parcels and density is often debated in those terms.

We propose to do some measurements using this definition of density to see if it has any relation at all to actual physical activity in a specific place.

2. Basic Formula

Residential Population in Residential Parcels = Persons in housing units per unit land area in residential parcels.

3. Detailed Formula

Residential Population in Residential Parcels = Persons in housing units as measured in the US Census at the block level per unit land area in residential parcels that is excluding rights of ways, water bodies, and land not in parcels.

4. Comments and Explanations

This calculation requires that your parcel layer contain land use information that can identify residential parcels.

5. GIS Approach

Use a definition query to display only residential parcels from the parcel layer. Intersect these residential parcels with the measurement geographies. Summarize the resulting layer's attribute table by measurement geography ID and sum the area. Apportion the census population by intersecting the census blocks with the measurement geographies. Summarize the resulting layer's attribute table by measurement geography ID and sum the population. For each measurement geography, divide the sum of apportioned population by the sum of residential hectares.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Parcel layer (polygon)
3. Census block layer (polygon) with field containing population
4. **XTools** extension (available from the Downloads section of the ESRI website)

Use a Definition Query to display only residential parcels

1. In the Table of Contents (the pane with the list of layers), right-click on the parcel layer and choose Properties
2. Go to the Definition Query tab and click Query Builder
3. Construct a SQL expression that applies to whichever field contains the land use data of the parcels and selects the values that identify residential uses
4. Click OK to close the Query Editor and then OK again to close the Layer Properties window.
5. Ensure that only the residential parcels in your parcel layer are displayed

Determine total area of residential parcels for each site:

5. Add the site layer and parcel layer to your Map Document.
6. Open the GeoProcessing Wizard.
 - g. Choose *Intersect two layers* and click *Next*
 - h. Select your parcels as the input layer
 - i. Select your study site layer as the overlay layer
 - j. Choose a name and location for the output layer
 - k. Click *Finish*
 - l. The new layer will be added to the Map Document
7. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - e. Under "Select layer to measure", select the layer created in the previous step
 - f. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - g. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - h. Hit OK
8. New fields called "Area" and "Hectares" will be created in the attribute table of your new parcel polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

Determine the apportioned census population figure for each site:

1. Add the site layer and census block layer to your Map Document.
2. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the census block layer
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
3. New fields called "Area" and "Hectares" will be created in the attribute table of your new census block polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).
4. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your census blocks as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
5. Open the Attribute Table of the census block layer created in the previous step.
 - a. Click on *Options* and choose *Add Field*
 - b. Name the field OrigHect and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the OrigHect field
 - d. Choose *Calculate Values*
 - e. In the Field Calculator, double click Hectares and click OK.
 - f. You have now copied the values from Hectares to OrigHect
6. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the clipped census block layer created in step 4 above
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)

- d. Hit OK
7. This will overwrite the values in the Hectares field with the new correct values (since the shapes have been clipped to the extent of the study site layer), yet the original number of hectares is preserved in the OrigHect field.
8. To perform the population apportionment, open the Attribute Table of the clipped census block layer again.
 - a. Click on *Options* and choose *Add Field*
 - b. Name the field PopSplit and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the PopSplit field
 - d. Choose *Calculate Values*
 - e. In the Field Calculator, double click Hectares, then hit the / button, then double click OrigHect, hit the * button, and finally double click the name of your Population field
 - f. Hit OK
9. The result is a field called PopSplit that contains the same proportion of the original census population figure as the proportion of the clipped census block area to the original area.

Calculate residential density:

7. For each of the two new layers (parcels and census blocks clipped to extent of study sites), do the following:
 - a. Open the layer's Attribute Table
 - b. Right-click on the name of the field containing the unique ID of the study site
 - c. Choose *Summarize*
 - d. In the box beneath *Choose one or more summary statistics...*, click the + next to Hectares
 - e. Check the box next to Sum
 - f. Choose a name and location for the output summary table
 - g. Click OK
8. Join one of the resulting summary tables to the other based on the study site ID field
9. Add a field called ResDensity of type double
10. Click Options and choose Calculate Values
11. In the Field Calculator, double click Sum_Popsplit, click the / button, and then double click the Sum_Hect field from the residential parcel summary table
12. Hit OK

The field ResDensity now contains the result of dividing the apportioned census population for a study site by the total area of residential parcels for the study site. The table can be joined with your study site shapefile based on the site ID, allowing you to copy the values into a new field you can create in the study site Attribute Table.

3.5 Population plus Employment per Unit Land Area (excluding water)

1. Basic Concept

Traditionally, population densities have been calculated in terms of people residing in an area. However, if density has some direct relation to walking (e.g. though there being a critical mass of people walking, via congestion, or via transit viability) then some kind of overall activity density is a better measure than merely residential density. Of course there are many kinds of activities that bring people to a place—e.g. employment, school, tourism, leisure. Of these employment is a major generator of movement and is also measured at a fine scale—though these very localized data are difficult to get access to.

A later version of this manual will discuss sources that have used this measure including (Messenger and Ewing 1996, 149-50)

2. Basic Formula

Population plus Employment per Unit Land Area = Persons in housing units plus total employees per unit land area (excluding water).

3. Detailed Formula

Population plus Employment per Unit Land Area = Persons in housing units as measured by the US Census at the block level plus total employees per unit land area (excluding water).

4. Comments and Explanations

Where census blocks are cut by the end of the measurement geography, the residential population is apportioned according to the percentage of land area falling inside and outside the line.

Employment data are quite varied. We changed the data we planned to use during the course of our study.

5. GIS Approach

[Note this uses employment data in grid cells, the result of a strategy to avoid confidentiality problems with state employment data. However, we ended out using Dun and Bradstreet point data so will redo these steps in the next version of the protocols.]

Add together the apportioned population and grid cell based employment for an area. Divide this figure by the total land area after adjusting for the area of the removed water features.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Census block layer with population data (polygon)
3. Grid cell employment data (polygon)
4. Water features layer (polygon)
5. **XTools** extension (available from the Downloads section of the ESRI website)

Refer to the fundamental protocol for calculating Net Land Area (excluding water). That protocol will create a study site layer that excludes water features and has updated area. In the rest of this protocol, any references to the study site layer assume that water features have been removed.

Add the study site layer and employment grid cell layers to your Map Document.

1. Open the Attribute Table of the employment grid cells.
2. Find the field containing the study site ID. Right-click on the name of the field and choose *Summarize*
3. In the box below 2. *Choose one or more summary statistics...*, click the + next to the name of the field containing the number of employees and then check the box for *Sum*
4. At the bottom of the dialog box, choose a name and location for the output summary table
5. Hit OK

Determine the apportioned census population figure for each site:

1. Add the site layer and census block layer to your Map Document.
2. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the census block layer

- b. Under “Desired output units”, choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
3. New fields called “Area” and “Hectares” will be created in the attribute table of your new census block polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).
4. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your census blocks as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
5. Open the Attribute Table of the census block layer created in the previous step.
 - a. Click on *Options* and choose *Add Field*
 - b. Name the field OrigHect and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the OrigHect field
 - d. Choose *Calculate Values*
 - e. In the Field Calculator, double click Hectares and click OK.
 - f. You have now copied the values from Hectares to OrigHect
6. From the XTools menu, select “Table Operations” and then “Calculate Area, Perimeter, Length, Acres, and Hectares” (follow instructions included with the extension for XTools installation).
 - a. Under “Select layer to measure”, select the clipped census block layer created in step 4 above
 - b. Under “Desired output units”, choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
7. This will overwrite the values in the Hectares field with the new correct values (since the shapes have been clipped to the extent of the study site layer), yet the original number of hectares is preserved in the OrigHect field.
8. To perform the population apportionment, open the Attribute Table of the clipped census block layer again.
 - a. Click on *Options* and choose *Add Field*
 - b. Name the field PopSplit and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the PopSplit field
 - d. Choose *Calculate Values*
 - e. In the Field Calculator, double click Hectares, then hit the / button, then double click OrigHect, hit the * button, and finally double click the name of your Population field
 - f. Hit OK
9. The result is a field called PopSplit that contains the same proportion of the original census population figure as the proportion of the clipped census block area to the original area.

Perform final calculation

1. In the Attribute Table of the clipped census block layer, right click on the name of the site ID field and choose Summarize
 - a. In the box beneath *Choose one or more summary statistics...*, click the + next to PopSplit
 - b. Check the box next to Sum
 - c. Choose a name and location for the output summary table
 - d. Click OK
2. Join the summary table of apportioned population and the summary table of employment into the study site layer table using the ID field

- a. Add a new field of type double that will contain the result of the population plus employment per hectare calculation
- b. Right click on this new field and choose Calculate Values
- c. In the Field Calculator, click the (button, double click on the PopSplit field, click the + button, double click the field containing the sum of employees, click the) button, click the / button, and finally double click on the Hectares field from the study site layer.
- d. Hit OK

The field you just calculated now contains the sum of apportioned population and total employment divided by the study site's area in hectares (excluding water).

3.6 Employment per Unit Land Area

1. Basic Concept

While residential population is the most often used density measure, and an overall activity density is likely important, a number of researchers have proposed that employment density may be associated with walking. In downtown areas, this is obvious as congestion makes automobiles less viable for transportation. However, in terms of the residential populations in the Twin Cities Walking Study, employment density in these neighborhoods is more likely a proxy of mixed use.

A later version of this manual will address prior studies using various employment density measures, although many were only of land in parcels e.g. Cervero and Kockelman (1996, 8), Ewing (1995, 55), Frank and Pivo (1994, 46-48).

2. Basic Formula

Employment per Unit Land Area = Total employees per unit land area (excluding water).

3. Detailed Formula

Employment Per Unit Area = Total employees per unit land area (excluding water).

4. Comments and Explanations

Area of water features is excluded in the calculation of area. The methods explained below are narrowly tailored to the nature of the employment data we purchased.

Employment is from Dun and Bradstreet with some checking of data.

5. GIS Approach

The approach to this measurement is to perform a spatial join between the employment data and the study sites for which employment density is needed. When doing the spatial join, calculate the sum of all employment. Finally, divide the total employment for each study site by its area.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Employment data (point)
3. Water features layer (polygon)
4. **XTools** extension (available from the Downloads section of the ESRI website)

Add the study site layer and employment layers to your Map Document.

Refer to the fundamental protocol for calculating Net Land Area (excluding water). Create a study site polygon layer that has had water features erased from it and area data updated. Join the summary table of employment to the Attribute Table of the study site layer with water removed based on the ID field.

1. Add a new field to the Attribute Table of type double called EmpPerHect or similar.
2. Right click on this field and choose Calculate Values
3. In the Field Calculator, double click the field containing the sum of employees, click the / button, and then double click the Hectares field from the study site table
4. Hit OK

The EmpPerHect field now contains the number of employees per hectare (excluding the area of water features).

3.7 Housing Units per Unit Land Area (gross, census data) (without water)

1. Basic Concept

Housing units per hectare are a proxy for population density. However, housing units rather than population is what is regulated by such mechanisms as zoning.

This measure uses census housing units. It would also be possible to use housing unit numbers from parcel data, and this might well be more accurate toward the end of the inter-censal period and in areas with a great deal of construction.

In the next version of the manual we will discuss earlier studies that used this measure e.g. Krizek (2003 APA, 269), McNally and Ryan (1993, 70).

2. Basic Formula

Housing Units per Unit Land Area = Total housing units as counted by the census per unit land area (excluding water).

3. Detailed Formula

Housing Units per Unit Land Area = Total housing units as counted by the census, including both occupied and unoccupied units, per unit land area (excluding water).

4. Comments and Explanations

Where census blocks are cut by the end of the measurement geography, the Number of housing units is apportioned according to the percentage of land area falling inside and outside the line.

5. GIS Approach

The approach to this measure is to intersect census blocks with the measurement geography and apportion the housing units to the measurement geographies. Divide the housing units by the total area.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Parcel layer (polygon)
3. Census block layer (polygon) with field containing housing units
4. Water features layer (polygon)
5. **XTools** extension (available from the Downloads section of the ESRI website)

Determine the apportioned census population figure for each site:

1. Add the site layer and census block layer to your Map Document.
2. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the census block layer
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
3. New fields called "Area" and "Hectares" will be created in the attribute table of your new census block polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).
4. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your census blocks as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
5. Open the Attribute Table of the census block layer created in the previous step.
 - a. Click on *Options* and choose *Add Field*
 - b. Name the field OrigHect and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the OrigHect field
 - d. Choose *Calculate Values*
 - e. In the Field Calculator, double click Hectares and click OK.
 - f. You have now copied the values from Hectares to OrigHect
6. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the clipped census block layer created in step 4 above
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
7. This will overwrite the values in the Hectares field with the new correct values (since the shapes have been clipped to the extent of the study site layer), yet the original number of hectares is preserved in the OrigHect field.
8. To perform the housing unit apportionment, open the Attribute Table of the clipped census block layer again.
 - a. Click on *Options* and choose *Add Field*
 - b. Name the field HUSplit and make it of type Double
 - c. Back in the Attribute Table, right click on the name of the HUSplit field
 - d. Choose *Calculate Values* in the Field Calculator, double click Hectares, then hit the / button, then double click OrigHect, hit the * button, and finally double click the name of your Housing Units field. Hit OK
9. The result is a field called HUSplit that contains the same proportion of the original census population figure as the proportion of the clipped census block area to the original area.

3.8 Lot Coverage (without water)

1. Basic Concept

This is a measure of perceived density and is literally how much ground is covered with buildings.

2. Basic Formula

Lot Coverage = Building footprint area divided by area in parcels excluding vacant or agricultural land uses.

3. Detailed Formula

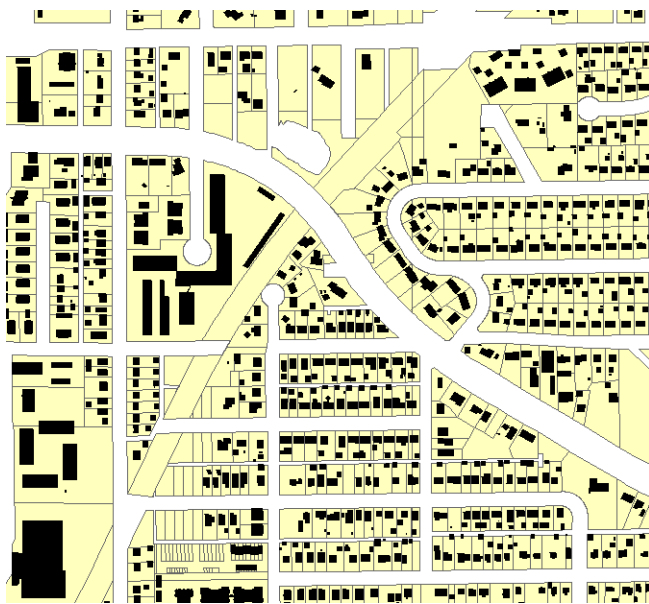
Same as above.

4. Comments and Explanations

Where buildings and/or parcels are cut by the end of the measurement geography, just slice them. This is an overall coverage measure for an entire measurement geography.

5. GIS Approach

Intersect building footprints with study sites and calculate area for the resulting layer. Perform a definition query on the parcel layer to exclude vacant for the resulting layer. Summarize the tables from the two layers resulting from the previous intersect procedures by measurement geography ID and generate the sum of the areas. Divide the sum of building footprint hectares by the sum of parcel areas for each measurement geography. t and agricultural areas, then intersect it with the measurement geographies and calculate area



6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field

2. Parcel layer (polygon)
3. Building footprints layer (polygon)
4. **XTools** extension (available from the Downloads section of the ESRI website)

Determine total area of building footprints for each site:

Add the site layer and building footprints layer to your Map Document.

Open the GeoProcessing Wizard.

- a. Choose *Intersect two layers* and click *Next*
- b. Select your building footprints as the input layer
- c. Select your study site layer as the overlay layer
- d. Choose a name and location for the output layer
- e. Click *Finish*
- f. The new layer will be added to the Map Document

From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).

- a. Under "Select layer to measure", select the layer created in the previous step
- b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
- c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
- d. Hit "OK"

New fields called "Area" and "Hectares" will be created in the attribute table of your new building footprints polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

Determine total area of parcels for each site:

1. Add the site layer and parcel layer to your Map Document.

2. Open the GeoProcessing Wizard.

- a. Choose *Intersect two layers* and click *Next*
- b. Select your parcels as the input layer
- c. Select your study site layer as the overlay layer
- d. Choose a name and location for the output layer
- e. Click *Finish*
- f. The new layer will be added to the Map Document

3. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).

- a. Under "Select layer to measure", select the layer created in the previous step
- b. Under "Desired output units", choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
- c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
- d. Hit "OK"

4. New fields called "Area" and "Hectares" will be created in the attribute table of your new parcel polygon layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

At this point you have a new parcel layer and a new building footprint layer. Both have been clipped to the extent of your study sites, and each feature in the two new layers should have a field containing the unique ID of the study site in which it is located.

For each of the two new layers, do the following:

1. Open the layer's Attribute Table
2. Right-click on the name of the field containing the unique ID of the study site
3. Choose *Summarize*
4. In the box beneath *Choose one or more summary statistics...*, click the + next to Hectares
5. Check the box next to Sum

6. Choose a name and location for the output summary table
7. Click OK

Final calculation

1. Join the summary table of building footprint area to the summary table of parcel area based on the study site ID field.
2. Add a field of type Double named LotCover or similar (this will contain the final desired result).
3. Right-click on the name of this new field and select Calculate Values
4. Click yes to bypass the question about not being in an edit session.
5. In the Field Calculator:
 - a. Using the list of available fields, double click on the Sum_Hectares field from the building footprint summary table
 - b. Click on the / button to the right
 - c. Double click on the Sum_Hectares field from the parcel summary table
 - d. Click OK to perform the calculation.

The result is a table with one record for each study site that also contains the lot coverage (building footprint area divided by parcel area). This table can be joined into the study site layer and the values copied over into a new field if desired.

The following variables are not proposed to be used in the study, so only a detailed formula is included.

3.9 Housing Units per Unit Land Area (parcel data)--Not Used in Study

Detailed Formula

Housing Units per Unit Land Area (parcel data)= Total housing units in parcels in parcel data, including occupied and unoccupied units of all sorts, per unit land area including land inside and outside parcels *but excluding water). Where buildings and / or parcels are cut by the end of the measurement geography, just slice them. This is an overall density measure for an entire measurement geography. Care needs to be taken with group quarters.

3.10 Housing Units per Unit Residential Land Area—Not Used in Study

Detailed Formula

Housing Units per Unit Residential Land Area = Total housing units as counted by the census per area of land in residential parcels (excluding water). Where census blocks are cut by the end of the measurement geography, the Number of housing units is apportioned according to the percentage of land area falling inside and outside the line.

Note: This is the housing unit equivalent of Residential Population in Residential Parcels. The next draft of this manual will relate this variable to dwellings per net area *in* Ewing (1995, 55).

3.11 Households per Unit Land Area (excluding water)—Not Used in Study

Detailed Formula

Households per Unit Land Area (excluding water) = Total households as counted by the census in blocks per unit land area (excluding water). Where census blocks are cut by the end of the measurement geography, the population is apportioned according to the percentage of land area falling inside and outside the line. See e.g. Rutherford et al (2000, 15).

4. PEDESTRIAN INFRASTRUCTURE

Chapter by: Ann Forsyth (drafting, conceptual issues and formulae, some comments and GIS approach text) and Joel Koepp (GIS Steps and the rest of the GIS approach/comments text)

Between Versions 2.0 and 2.2 there were significant updates to protocols 4.3, 4.6, 4.7, 4.8, 4.10, and 4.11.

Background

Pedestrian infrastructure includes the built and planted features that provide pedestrian amenities or that affect pedestrian mobility, safety, and comfort. From marked pedestrian crossings to street trees, these are more open to modification than the basic street pattern. This dimension matters because:

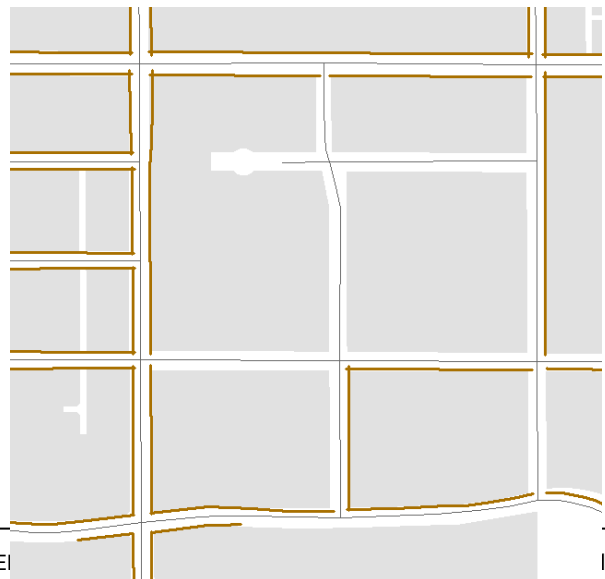
- Pedestrians are exposed to the outdoor elements—amenities can make walking much more enjoyable.
- Pedestrians have unique safety concerns, some of which are affected by design features e.g. street lights, pedestrian crossings.
- The street pattern and pedestrian infrastructure such as sidewalks do not always coincide—some areas with gridded street patterns do not have sidewalks; some areas with superblocks and culs-de-sac have pedestrian path and trail networks (Forsyth 2002). Examining pedestrian infrastructure can uncover some of this complexity.

However, measurements of this dimension are the least developed because data are incomplete or unavailable, so measurement includes data collection as well as analysis. Some studies assume that more “traditional” neighborhoods with gridded streets and high connectivity possess good pedestrian infrastructure. However, more detailed measures have been developed based on field observations, interviews, and GIS based indicators such as completeness of the sidewalk system (Hess et al. 1999).

4.1 Sidewalk Length per Unit Area

1. Basic Concept

Sidewalks are thought to support walking. Intuitively, this is likely to be the case on busy roads though the relationship is less clear in the case of slower roads. Sidewalk length in an area also reflects the density of streets compared with the ratio of sidewalks to roads. One could imagine a moderate value on this measure with both a very dense street network with sidewalks on some streets or a street pattern with larger blocks but a complete sidewalk system. Both may promote walking.



2. Basic Formula

Sidewalk Length in an Area = Sum together the length of all sidewalk segments in a particular area.

3. Detailed Formula

Sidewalk Length in an Area = Total sidewalk

Figure 1: Sidewalks in a neighborhood along some streets and not others

length of all sidewalks in area where they are located along public rights of way. This excludes sidewalks in parks, informal paths, and cuts-through. [The next version will explain the case of sidewalks connecting dead end streets—we had few of these.]

4. Comments and Explanations

Sidewalk data are inconsistently collected. As explained in Chapter 1, we digitized all sidewalks from high resolution orthophotos of the area and field checked the data.

5. GIS Approach

The GIS approach is to perform a spatial intersect between the sidewalks and the study sites. Open the attributes of the resulting layer and summarize the data using the unique study site ID field. When doing the table summary, calculate the Sum of the Length field. The new table created will be the sum of the length of all sidewalk segments for each study site.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Sidewalk layer (polyline)
3. **XTools** extension (available from the Downloads section of the ESRI website)

Add the site layer and sidewalk layer to your Map Document.

1. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your sidewalks as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
2. From the XTools menu, select “Table Operations” and then “Calculate Area, Perimeter, Length, Acres, and Hectares” (follow instructions included with the extension for XTools installation).
 - a. Under “Select layer to measure”, select the clipped sidewalk layer created in the previous step
 - b. Under “Desired output units”, choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now
 - d. Hit “OK”
3. Open the Attribute Table of the new sidewalk layer
 - a. Right click on the name of the unique study site ID field and choose *Summarize*
 - b. Click the + to expand the Length field and check the box next to *Sum*
 - c. Select a name and location for the output summary table
 - d. Click OK

This summary table contains records for all the study sites, along with a Sum_Length field that contains the total length of all sidewalks in the study site.

4.2 Sidewalk Length Divided by Road Length

1. Basic Concept

More complete and continuous sidewalks are thought to support walking. This measure focuses on the proportion of the road network that has sidewalks.

The next version of these protocols will discuss the previous uses of this measure e.g. Hess et al (1999, 10).

2. Basic Formula

Sidewalk Length Divided by Road Length = Sum together the length of all sidewalk segments along public rights of way and divide by the length of all road centerlines.

3. Detailed Formula

Sidewalk Length Divided by Road Length = Sum together the length of all sidewalk segments along public rights of way and divide by the length of all road centerlines for roads where pedestrians have access i.e. excluding interstates and other limited access roads. Divided roads are counted as one.

4. Comments and Explanations

Where sidewalks and/or roads are cut by the end of the measurement geography, just slice them. This is an overall ratio measure for an entire measurement geography.

The results of this calculation can vary based on which definition of “roads” is used, i.e., whether or not freeway entrance/exit ramps are included, length of divided roads is averaged, etc. See the protocol for Road Length per Hectare for more details.

The area that we studied did not have private roads.

5. GIS Approach

Use the GeoProcessing Wizard to intersect sidewalks with measurement geographies. Use XTools to recalculate the lengths of all sidewalk segments. Finally, summarize the intersected sidewalks by measurement geography ID, calculating the sum of the Length field in the process.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Road features layer (polyline)
3. Sidewalk layer (polyline)
4. **XTools** extension (available from the Downloads section of the ESRI website)

Refer to the earlier Protocol 4.1 on calculating sidewalk length. Once a summary table of sidewalk length by study site exists, perform calculation of road length:

Add the roads layer and study sites layer to a new ArcMap document

In Arc Toolbox, go to *Analysis Tools* → *Overlay* and select *Intersect*

Under Input Features, select both the roads layer and the study sites

Under Output Feature Class, choose a name and location for the output layer

Click OK

The new layer will be added to the Map Document
 In Arc Toolbox, go to *Data Management Tools* → *Generalization* and select *Dissolve*
 For *Input Features*, select the layer created in step 3
 Under *Output Feature Class*, choose a name and location for the output file
 Under *Dissolve_Field(s)*, check the box for the field containing the unique ID of your study sites
 Click OK
 The resulting file should consist of road segments and have the same number of features as you have study sites

To complete the calculation, divide the length of all sidewalks in a study site (from the summary table created earlier) by the length of all roads in that study site.

4.3 Sidewalk Length per Length of Major Road

1. Basic Concept

The basic idea behind this measure is that sidewalks are more important on major roads than on side streets. Ann Vernez Moudon (2004) and her team have used the measure.

2. Basic Formula

Sidewalk Length Divided by Length of Major Road = Length of sidewalks along major roads only divided by the length of those major roads in an area.

3. Detailed Formula

Sidewalk Length Divided by Length of Major Road = Using major roads only, sum together the length of all sidewalk segments along public rights of way on those roads and divide by the length of all road centerlines after removing roads with no pedestrian access and averaging the length of divided roads.

4. Comments and Explanations

As Vernez Moudon had a different road file, we defined major roads as roads larger than neighborhood streets but smaller than interstates and US highways (four lane divided, limited access roads not available to pedestrians). This is possible using the *F_CLASS* field in the roads data. Selecting roads of *F_CLASS* 'A30' and 'A25' will identify the collectors and arterials to be used as major roads. We removed by hand certain roads within this group known to be four lane divided with no pedestrian access.

5. GIS Approach

Select features with *F_CLASS* = 'A25' OR 'A30' from the roads file, and average the lengths of divided roads to create a major roads layer. Intersect the major roads with measurement geographies. Summarize the Attribute Table of the

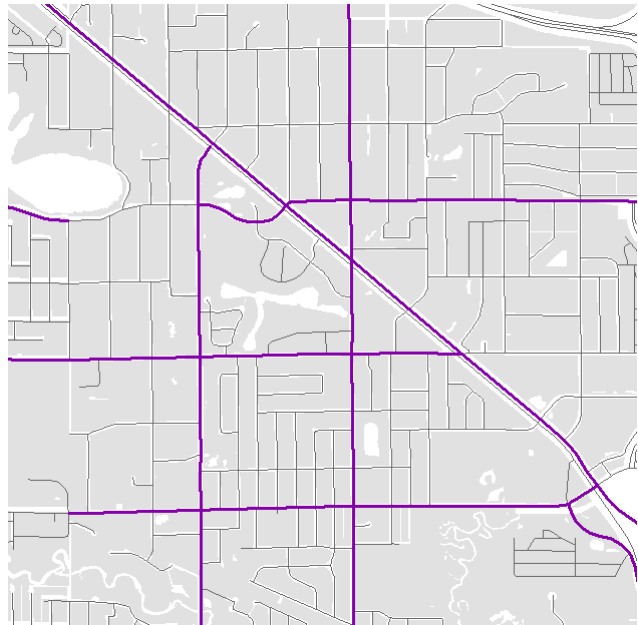


Figure 2: Major roads (collectors and arterials) differentiated from other roads. These roads often have attractive destinations but also have problems of traffic safety

resulting layer and calculate the length of all major roads in each study site. Use Select by Location to identify features in the sidewalks layer that are within a certain distance (e.g., 10 meters) of the major roads and save them as a new layer. Use the GeoProcessing Wizard to intersect the sidewalks along major roads with measurement geographies. Use XTools to recalculate the lengths of all sidewalk segments. Summarize the attribute table of intersected sidewalks by measurement geography ID, calculating the sum of the Length field in the process. Divide each site's sidewalk length by the length of its major roads.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Sidewalk layer (polyline)
3. Roads layer (polyline)
4. **XTools** extension (available from the Downloads section of the ESRI website)

Calculate length of major roads

1. Right click on the roads layer and choose Data→Export Data to make a copy of the roads layer for the purpose of editing
2. Choose a location for the output file and name it major_roads or similar
3. Click Yes to add the new layer to the view
4. Go to the Editor toolbar and select Editor→Start Editing
 - a. Select the directory that contains the major roads layer and click OK
 - b. Open the Selection menu and choose Select By Attributes
 - c. Select the major roads layer in the top drop down box
 - d. Make sure the method is Create a new selection
 - e. Type out an expression that will identify non-walkable roads (freeways and on/off ramps), such as "F_CLASS" <= 'A25' OR "F_CLASS" > 'A30'
 - e. Double check that all the roads intended to be removed are selected, then hit the Delete key to remove them
 - f. For every divided road, use the Edit Tool from the Editor Toolbar to select one of the two segments and delete it
 - g. When all edits are complete, go to the Editor Toolbar and choose Editor→Stop Editing, clicking Yes when prompted to save edits
5. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your major roads as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
6. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the intersected major roads layer created in the previous step
 - b. Under "Desired output units", choose *Meters*
 - c. Hit "OK"
7. Open the Attribute Table of the intersected major roads layer
 - a. Right click on the name of the unique study site ID field and choose *Summarize*
 - b. Click the + to expand the Length field and check the box next to *Sum*
 - c. Select a name and location for the output summary table
 - d. Click OK

This summary table contains records for all the study sites, along with a Sum_Length field that contains the total length of all major roads in the study site.

1. Add the site layer and sidewalk layer to your Map Document.
 - a. Open the *Selection* menu and choose *Select By Location*
 - b. In the top drop down box, choose *select features from*
 - c. Check the box next to the sidewalks layer
 - d. In the second drop down box, choose *are within distance of*
 - e. In the last drop down box, choose the major roads layer
 - f. Check the box next to *Apply a buffer to the features...* and enter a distance and the units (e.g., 10 meters)
 - g. Click *Apply*
 - h. In the Table of Contents, right click on the sidewalks layer and choose *Data→Export Data*
 - i. Save the selected features to a new layer named *major_sidewalks* or similar
2. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your major sidewalks as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
3. From the XTools menu, select “Table Operations” and then “Calculate Area, Perimeter, Length, Acres, and Hectares” (follow instructions included with the extension for XTools installation).
 - a. Under “Select layer to measure”, select the sidewalk layer created in the previous step
 - b. Under “Desired output units”, choose your units (depending on the study site size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now
 - d. Hit “OK”
4. Open the Attribute Table of the new major sidewalk layer
 - a. Right click on the name of the unique study site ID field and choose *Summarize*
 - b. Click the + to expand the Length field and check the box next to *Sum*
 - c. Select a name and location for the output summary table
 - d. Click OK

This summary table contains records for all the study sites, along with a Sum_Length field that contains the total length of all sidewalks along major roads in the study site.

To complete the calculation, use the two summary tables created using these instructions. For each study site, divide the length of sidewalks along the major roads by the length of all major roads.

4.4 Street Lights per Length of Road

1. Basic Concept

Safety from accidents and crime is an important issue for pedestrians. Lighting improves both forms of safety at night.

The next version of these protocols will review previous uses of related variables e.g. Cervero and Kockelman (1996, 8,16) who examined the average distance between lights.

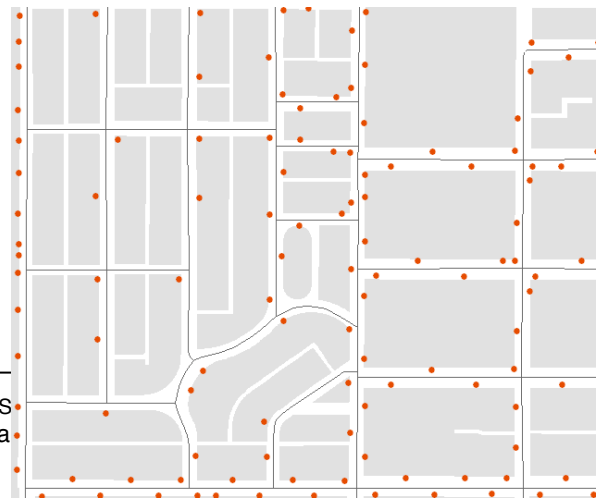


Figure 3: Street lights in a neighborhood indicated by dots at the location of the base of the post

2. Basic Formula

Street Lights per Length of Road = Number of street lights divided by total length of road centerlines.

3. Detailed Formula

Street Lights per Length of Road = Number of street lights (multiple headed fixtures classed as one) divided by total length of road centerlines for roads that are accessible to pedestrians (i.e. not limited access highways).

4. Comments and Explanations

Where roads are cut by the end of the measurement geography, just slice them. This is an overall ratio measure for an entire measurement geography.

5. GIS Approach

Perform a spatial join between the street lights and the measurement geographies to determine the number of street lights in each measurement geography. Intersect the roads layer with the measurement geographies. With the resulting layer, open the attributes and summarize the table using the field containing the unique measurement area ID. When summarizing the table, calculate the sum of all fields containing numbers, which will result in an output table with a field containing the length of all road segments. Divide the number of street lights in each measurement geography by the total road length in that measurement geography.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Street lights layer (point)
3. Roads layer (polyline)
4. **XTools** extension (available from the Downloads section of the ESRI website)

Add the site layer and street lights layer to your Map Document.

1. Perform a Spatial Join on your new buffer layer
 - a. Right click on your new layer and select *Joins and Relates* and then *Join...*
 - b. Under "What do you want to join to this layer?" select *Join data from another layer based on spatial location*
 - c. Under "1. Choose the layer to join to this layer" select your clipped intersection layer (point)
 - d. Under "2. You are joining:" select the first option *Each polygon will be given a summary...*
 - e. Under "How do you want the attributes to be summarized?" check the box for *Sum*
 - f. Under "3. The result of the join will be saved..." give your new layer a name
 - g. Click on OK

Add the roads layer to your Map Document.

1. Open the GeoProcessing Wizard.
 - a. Choose *Intersect two layers* and click *Next*
 - b. Select your roads as the input layer
 - c. Select your study site layer as the overlay layer
 - d. Choose a name and location for the output layer
 - e. Click *Finish*
 - f. The new layer will be added to the Map Document
2. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).

- a. Under “Select layer to measure”, select the clipped roads layer created in the previous step
 - b. Under “Desired output units”, choose *Meters*
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now
 - d. Hit “OK”
3. Open the Attribute Table of the new roads layer
 - a. Right click on the name of the unique study site ID field and choose *Summarize*
 - b. Click the + to expand the Length field and check the box next to *Sum*
 - c. Select a name and location for the output summary table.
 - d. Click OK

You now have a summary table of road length in meters by study site. Join this table into the table of the layer that resulted from the spatial join of lights to study sites above (based on the site ID field).

1. Add a field of type double to hold the result of your street lights per meter calculation.
2. Right click on this new field in the Attribute Table and choose Calculate Values
3. In the field selector box, double click the field containing the number of street lights, then click the / button, and finally double click the field containing the length of roads
4. Hit OK

4.5 Street Trees (trees within an X distance buffer) per Length of Road

1. Basic Concept

Street trees are thought to improve pedestrian comfort (shade, wind protection) and the attractiveness of the street. While this is a measure per length of road, it is in many ways a density measure weighted by road length, as all trees within a certain area are being counted.

A later version of these protocols will examine the use of related concepts by earlier researchers e.g. Cervero and Kockelman (1996, 8,) who looked at the proportion of blocks with street trees.

2. Basic Formula

Street Trees (trees within a 15/20 meter buffer) per Length of Road = Number of street trees within a buffer distance of 15/20 meters of the road centerline per length of road.

3. Detailed Formula

The size of the road buffer depends on the character of the road. For city streets, the buffer is 15 meters from the street centerline. For arterials and larger roads, the buffer is 20 meters from the centerline. These roads were identified by querying the F_CLASS (functional class) field for values less than or equal to A30 (A30 is typically a major arterial, A20 a state or US highway, and A10 an interstate).



Figure 4: Only trees found within the road buffer are counted

4. Comments and Explanations

We digitized trees from high resolution digital orthophotos. Where trees had a continuous canopy so that marking individual trees was difficult, tree stands were photographed and then sorted into high, medium, and low density. We measured densities of trees in three areas and used these figures, and some research on tree density ranges, to allocate trees into general density ranges with a clear upper limit. The upper limit was so that a very dense stand in one area, that may be perceived similarly to a stand that is much less dense but still has a lot of trees, did not bias the tree density too much. The working density figures are 60 trees per acre for low density, 200 for medium density, and 400 for high density. However, these figures are subject to review as we refine these measurements. Trees can reach very high densities, well over 1,000 per acre.

5. GIS Approach

The GIS approach to this calculation requires two stages. First, a spatial join between the road buffer and the tree points will yield the count of trees per study site. Next, the road buffer must be intersected with the tree polygons (which represent dense stands of trees) and the count of trees must be determined by calculating the area of the resulting features and multiplying it by the assigned tree density. Finally, the count of tree points and count of trees in polygons must be added together and divided by the area of the road buffer.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Roads layer (polyline)
3. Trees layer (point)
4. Tree stands layer (polygon) with a field containing the density
5. **XTools** extension (available from the Downloads section of the ESRI website)

Prepare roads layer for buffering

1. Open the Attribute Table of the roads layer
2. Click on *Options* and choose *Add Field*
3. Name the field BuffDist and make it of type Short Integer, then click OK
4. Click on *Options* and choose *Select by Attributes*
5. Double click the field "F_CLASS", then click the <= button, and then select 'A30' from the unique values
6. Click *Apply* to select major arterials from the roads layer
7. In the Attribute Table, right click the name of the BuffDist field and choose *Calculate Values*
8. Type in 20 and click OK to assign a value of 20 to the selected records
9. In the Attribute Table, click *Options* and choose *Switch Selection*
10. Right click the name of the BuffDist field and choose *Calculate Values*
11. Type in 15 and click OK to assign a value of 15 to the selected records

Buffer road features

1. In Arc Toolbox, open *Analysis Tools* → *Proximity*, and select *Buffer*.
2. In the *Buffer* tool window, under *Input Features* select your roads layer
3. Under *Output Feature Class*, choose a name and location for the output shapefile
4. For *Distance*, click *Field* and select the BuffDist field from the list
5. Click OK

Create road buffers for each study site

1. In Arc Toolbox, go to *Analysis Tools* → *Overlay* and select *Intersect*

2. Under Input Features, select both the buffered roads layer from the previous step and the study sites
3. Under Output Feature Class, choose a name and location for the output layer
4. Click OK
5. The new layer will be added to the Map Document
6. In Arc Toolbox, go to *Data Management Tools* → *Generalization* and select *Dissolve*
7. For *Input Features*, select the layer created in step 3
8. Under *Output Feature Class*, choose a name and location for the output file
9. Under *Dissolve_Field(s)*, check the box for the field containing the unique ID of your study sites
10. Click OK
11. The resulting file should consist of road buffers and have the same number of features as you have study sites

Count tree points

1. In the Table of Contents pane, right click on the road buffers layer created in the last step and go to *Join and Relates* → *Join*
2. Choose to Join data from another layer based on spatial location
3. Below, click the radio button that provides a summary of numeric attributes
4. Choose a name and location for the output file and click OK

Count trees in tree stands

1. In Arc Toolbox, go to *Analysis Tools* → *Overlay* and select *Intersect*
2. Under *Input Features*, select both the buffered roads layer from the previous step and tree stands layer
3. Under *Output Feature Class*, choose a name and location for the output layer
4. Click OK
5. The new layer will be added to the Map Document
6. In Arc Toolbox, go to *Data Management Tools* → *Generalization* and select *Dissolve*
7. For *Input Features*, select the layer created in step 3
8. Under *Output Feature Class*, choose a name and location for the output file
9. Under *Dissolve_Field(s)*, check the boxes for the field containing the unique ID of your study sites and the unique ID of the tree stands
10. Under *Statistics Field(s)*, choose Density
11. Set the *Statistic Type* to be First
12. Click OK
13. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the output layer from the dissolve above
 - b. Under "Desired output units", choose your units (depending on the study site size, try *Miles*, *Meters*, or *Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit OK
 - e. New fields called "Area" and "Hectares" will be created in the attribute table of your new census block polygon layer with the areas of each polygon calculated in the units you chose (Area) and in Hectares (Hectares).
14. Open the Attribute Table of the layer of created in the dissolve procedure above
15. Click on *Options* and choose *Add Field*
16. Name the field Trees and set it to type Double, then hit OK
17. Right click on the name of this field and do *Calculate Values*
18. Double click the name of the Density field (First_Dens), then click the * button, finally double click the Hectares field and hit OK
19. This will calculate the number of trees in each tree stand based on the density and area.
20. In the Attribute Table, right click on the field containing the study site unique ID and choose *Summarize*
21. For the Trees field, check the box to calculate the Sum summary statistic

22. Choose a name and location for the output table
23. This summary table should contain one record for each study site and the total number of trees in tree stands for each.

Add together the count of tree points and count of trees in tree stands for each study site. Refer to the protocol for calculating road length to calculate it, then divide the total trees for each study site by its total road length.

Note, the next variables use data from an urban design inventory that uses sample data and may need to be modified for 100% data

4.6 Percent of Street Segments with Marked Pedestrian Crossings at One or Both Ends

1. Basic Concept

Marked pedestrian crossings may help pedestrian movement, though they may also indicate busy streets. This measure is very broad and looks for at least some marked crossings and does not require all potential crossing areas to be marked. If it becomes interesting

This variable is based on the following inventory question that was filled in for both ends of the segment.

2a. Consider the places on the segment that are **intended** for pedestrians to cross the street. Are these places marked for pedestrian crossing?

All = 3; Some = 2; none = 0; NA = 8 (lines 7 and 211 of inventory)

2. Basic Formula

Percent of Street Segments with Marked Pedestrian Crossings at One or Both Ends = Total street segments in area that were sampled, divided by the number that score 2 or 3 on this variable at one or both ends.

3. Detailed Formula

As above.

4. Comments and Explanations

None.

5. GIS Approach

The GIS approach to creating this variable begins with identifying which sampled road segments have marked pedestrian crossings. Perform a spatial intersect between the sampled road segments and the measurement geography. The output needs to be dissolved using both the unique measurement geography ID and the unique road segment ID (in case the features of the measurement geography overlap each other). The attribute table of the dissolved output must then be summarized using the measurement geography ID field. This will yield a new table containing both a count of the number of road segments with marked crossings and the total number of road segments. Divide the number of segments with marked crossings by the total to determine the percentage.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0.

To complete this protocol you will need:

1. Site layer (polygon)
2. Roads layer (polyline) with unique ID for each road segment
3. Urban Design Inventory (table) with road segment IDs

Identify sampled roads with marked pedestrian crossings

1. Add the sampled roads layer and Urban Design Inventory table to an ArcMap document
 - a. Right click on the Inventory table and choose *Joins and Relates*→*Relate*
 - b. In item 1 of the Relate dialog box, choose the field in the Inventory table that contains the unique road segment ID (in our case, Line1)
 - c. In item 2, choose the sampled roads layer
 - d. In item 3, select the field from the sampled roads layer that contains the unique ID (in our case, TLGID)
 - e. Click OK
2. Right click the Inventory table and choose *Open*
 - a. A road segment with a marked crossing at either end will be counted as having marked crossings
 - b. Click *Options* and choose *Select By Attributes*
 - c. Enter the expression "Line7" <> 0 OR "Line211" <> 0 and hit *Apply*, then *Close*
 - d. This will select the road segments that have one or more ends with marked crossings
3. Click *Options* and choose *Related Tables*→*Relate1* to open the sampled roads layer and select the matching records
 - a. In the sampled roads Attribute Table, select *Options*→*Add Field*
 - b. Name the field Crossings and make it of type Short Integer, then hit OK
 - c. Right click on the new Crossings field and choose *Calculate Values*
 - d. Enter 1 and hit OK to assign a value of 1 to the highlighted records (sampled roads that have crossings at one or both ends)

Combine sampled roads and measurement geographies

1. Intersect the roads and measurement geographies
 - a. In ArcToolbox, open the *Analysis Tools*→*Overlay*→*Intersect* tool
 - b. Select the sampled roads and the measurement geography as the Input Features
 - c. Choose a name and location for the Output Feature Class
 - d. Hit OK
2. Open the *Data Management Tools*→*Generalization*→*Dissolve* tool
 - a. Select the output layer from the Intersect tool above as the Input Feature
 - b. Choose a name and location for the Output Feature Class
 - c. Select both the unique measurement geography ID and the unique sampled road ID as the Dissolve Fields
 - d. Choose Crossings as the Statistics field and set the Statistic Type to MAX or MIN (it doesn't matter which one, this is just a way of preserving the field and carrying it over to the output file)
 - e. Hit OK

Count roads and roads with crossings

2. Open the Attribute Table of the output layer from the Dissolve tool process
 - a. Right click on the field containing the unique ID of the measurement geographies and choose *Summarize*
 - b. In the dialog box that appears, click the + symbol next to the MAX_Crossings field and check the box for Sum to calculate the sum of that field as a summary statistic
 - c. Choose a name and location for the output summary table
 - d. Hit OK
 - e. Click *Yes* to add the table to the ArcMap document
3. Open the summary table

- a. Click *Options* and choose *Add Field*
- b. Name it PctCross or similar and set it to type Double
- c. Right click the added field in the table and choose *Calculate Values*
- d. In the dialog box, enter the expression $[SUM_MAX_Cr] / [Count]$ (the field names may be slightly different depending on the names you chose earlier)
- e. Hit *OK*

This divides the number of segments with marked crossings by the total number of sampled segments for each feature in the measurement geographies

4.7 Percent of Street Segments with Visible Litter, Graffiti, or Dumpsters

1. Basic Concept

General maintenance and cleanliness is thought to affect attractiveness and a sense of safety for pedestrians.

This variable is based on the following inventory questions.

44. How much **graffiti** is apparent on this segment?

Some/a lot = 3; little = 2; none = 0 (line 166)

45. How much **litter** is apparent on this segment?

Some/a lot = 3; little = 2; none = 0 (line 167)

46. Are there **dumpsters** visible on this segment?

Some/a lot = 3; few = 2; none = 0 (Line 168)

2. Basic Formula

Percent of Street Segments with Visible Litter, Graffiti, or Dumpsters = The total number of inventory segments in an area with at least one instance of “some/a lot” (i.e. score 3) of graffiti, litter, or dumpsters visible, divided by the total number of segments sampled in an area.

3. Detailed Formula

As above.

4. Comments and Explanations

None.

5. GIS Approach

The GIS approach to creating this variable begins with identifying which sampled road segments have visible litter, graffiti, or dumpsters. Perform a spatial intersect between the sampled road segments and the measurement geography. The output needs to be dissolved using both the unique measurement geography ID and the unique road segment ID (in case the features of the measurement geography overlap each other). The attribute table of the dissolved output must then be summarized using the measurement geography ID field. This will yield a new table containing both a count of the number of road segments with visible litter, etc. and the total number of road segments. Divide the number of segments with visible litter, etc. by the total to determine the percentage.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0.

To complete this protocol you will need:

1. Site layer (polygon)
2. Roads layer (polyline) with unique ID for each road segment
3. Urban Design Inventory (table) with road segment IDs

Identify sampled roads with visible litter, graffiti, or dumpsters

1. Add the sampled roads layer and Urban Design Inventory table to an ArcMap document
 - a. Right click on the Inventory table and choose *Joins and Relates*→*Relate*
 - b. In item 1 of the Relate dialog box, choose the field in the Inventory table that contains the unique road segment ID (in our case, Line1)
 - c. In item 2, choose the sampled roads layer
 - d. In item 3, select the field from the sampled roads layer that contains the unique ID (in our case, TLGID)
 - e. Click OK
2. Right click the Inventory table and choose *Open*
 - a. Click *Options* and choose *Select By Attributes*
 - b. Enter the expression "Line166" = 3 OR "Line167" = 3 OR "Line168" = 3 and hit *Apply*, then *Close*
 - c. This will select the road segments that are defined as having visible litter, graffiti, or dumpsters
3. Click *Options* and choose *Related Tables*→*Relate1* to open the sampled roads layer and select the matching records
 - a. In the sampled roads Attribute Table, select *Options*→*Add Field*
 - b. Name the field Litter and make it of type Short Integer, then hit OK
 - c. Right click on the new Litter field and choose *Calculate Values*
 - d. Enter 1 and hit OK to assign a value of 1 to the highlighted records (sampled roads that have visible litter, etc)

Combine sampled roads and measurement geographies

1. Intersect the roads and measurement geographies
 - a. In ArcToolbox, open the *Analysis Tools*→*Overlay*→*Intersect* tool
 - b. Select the sampled roads and the measurement geography as the Input Features
 - c. Choose a name and location for the Output Feature Class
 - d. Hit OK
2. Open the *Data Management Tools*→*Generalization*→*Dissolve* tool
 - a. Select the output layer from the Intersect tool above as the Input Feature
 - b. Choose a name and location for the Output Feature Class
 - c. Select both the unique measurement geography ID and the unique sampled road ID as the Dissolve Fields
 - d. Choose Litter as the Statistics field and set the Statistic Type to MAX or MIN (it doesn't matter which one, this is just a way of preserving the field and carrying it over to the output file)
 - e. Hit OK

Count roads and roads with visible litter, graffiti, or dumpsters

1. Open the Attribute Table of the output layer from the Dissolve tool process
 - a. Right click on the field containing the unique ID of the measurement geographies and choose *Summarize*
 - b. In the dialog box that appears, click the + symbol next to the MAX_Litter field and check the box for Sum to calculate the sum of that field as a summary statistic
 - c. Choose a name and location for the output summary table
 - d. Hit OK
 - e. Click *Yes* to add the table to the ArcMap document
2. Open the summary table
 - a. Click *Options* and choose *Add Field*
 - b. Name it PctLitt or similar and set it to type Double

- c. Right click the added field in the table and choose *Calculate Values*
- d. In the dialog box, enter the expression [SUM_MAX_Li] / [Count] (the field names may be slightly different depending on the names you chose earlier)
- e. Hit OK

This divides the number of segments with visible litter, graffiti, or dumpsters by the total number of sampled segments for each feature in the measurement geographies

4.8 Percent of Street Segments with Traffic Calming, Broadly Defined

1. Basic Concept

This variable is based on the following inventory questions.

- 51. Are there measures on this segment that could **slow down traffic**? Mark all that apply. Speed bump/speed hump/raised crosswalk; or dips (that are intended to slow down traffic)
yes = 1; no = 0 (line 177)
- Rumble strips or bumps (includes dots, reflectors, raised concrete strips, etc.)
yes = 1; no = 0 (line 178)
- Curb bulb out/curb extension
yes = 1; no = 0 (line 179)
- Traffic circle/roundabout
yes = 1; no = 0 (line 180)
- Median
yes = 1; no = 0 (line 181)
- Angled/ On-street parking (that runs along most or the entire segment - does not have to be on both sides of segment)
yes = 1; no = 0 (line 183)
- Other
yes = 1; no = 0 (line 184)

2. Basic Formula

Percent of Street Segments with Traffic Calming, Broadly Defined = The total number of inventory segments in an area with at least one instance of one of the features above, divided by the total number of segments sampled in an area.

3. Detailed Formula

As above.

4. Comments and Explanations

None.

5. GIS Approach

The GIS approach to creating this variable begins with identifying which sampled road segments have traffic calming. Perform a spatial intersect between the sampled road segments and the measurement geography. The output needs to be dissolved using both the unique measurement geography ID and the unique road segment ID (in case the features of the measurement geography overlap each other). The attribute table of the dissolved output must

then be summarized using the measurement geography ID field. This will yield a new table containing both a count of the number of road segments with traffic calming and the total number of road segments. Divide the number of segments with traffic calming by the total to determine the percentage.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0.

To complete this protocol you will need:

1. Site layer (polygon)
2. Roads layer (polyline) with unique ID for each road segment
3. Urban Design Inventory (table) with road segment IDs

Identify sampled roads with visible litter, graffiti, or dumpsters

1. Add the sampled roads layer and Urban Design Inventory table to an ArcMap document
 - a. Right click on the Inventory table and choose *Joins and Relates*→*Relate*
 - b. In item 1 of the Relate dialog box, choose the field in the Inventory table that contains the unique road segment ID (in our case, Line1)
 - c. In item 2, choose the sampled roads layer
 - d. In item 3, select the field from the sampled roads layer that contains the unique ID (in our case, TLGID)
 - e. Click OK
2. Right click the Inventory table and choose *Open*
 - a. A road segment with a value of 1 for at least one of the seven questions will be counted as having traffic calming
 - b. Click *Options* and choose *Select By Attributes*
 - c. Enter the expression "Line177" <> 0 OR "Line178" <> 0 OR "Line179" <> 0 OR "Line180" <> 0 OR "Line181" <> 0 OR "Line183" <> 0 OR "Line184" <> 0 and hit *Apply*, then *Close*
 - d. This will select the road segments that have at least one element of traffic calming
3. Click *Options* and choose *Related Tables*→*Relate1* to open the sampled roads layer and select the matching records
 - a. In the sampled roads Attribute Table, select *Options*→*Add Field*
 - b. Name the field Calming and make it of type Short Integer, then hit OK
 - c. Right click on the new Calming field and choose *Calculate Values*
 - d. Enter 1 and hit OK to assign a value of 1 to the highlighted records (sampled roads that have traffic calming)

Combine sampled roads and measurement geographies

1. Intersect the roads and measurement geographies
 - a. In ArcToolbox, open the *Analysis Tools*→*Overlay*→*Intersect* tool
 - b. Select the sampled roads and the measurement geography as the Input Features
 - c. Choose a name and location for the Output Feature Class
 - d. Hit OK
2. Open the *Data Management Tools*→*Generalization*→*Dissolve* tool
 - a. Select the output layer from the Intersect tool above as the Input Feature
 - b. Choose a name and location for the Output Feature Class
 - c. Select both the unique measurement geography ID and the unique sampled road ID as the Dissolve Fields
 - d. Choose Calming as the Statistics field and set the Statistic Type to MAX or MIN (it doesn't matter which one, this is just a way of preserving the field and carrying it over to the output file)
 - e. Hit OK

Count roads and roads with visible traffic calming

1. Open the Attribute Table of the output layer from the Dissolve tool process
 - a. Right click on the field containing the unique ID of the measurement geographies and choose *Summarize*
 - b. In the dialog box that appears, click the + symbol next to the MAX_Calming field and check the box for Sum to calculate the sum of that field as a summary statistic
 - c. Choose a name and location for the output summary table
 - d. Hit *OK*
 - e. Click *Yes* to add the table to the ArcMap document
2. Open the summary table
 - a. Click *Options* and choose *Add Field*
 - b. Name it PctCalm or similar and set it to type Double
 - c. Right click the added field in the table and choose *Calculate Values*
 - d. In the dialog box, enter the expression $[SUM_MAX_Ca] / [Count]$ (the field names may be slightly different depending on the names you chose earlier)
 - e. Hit *OK*

This divides the number of segments with traffic calming by the total number of sampled segments for each feature in the measurement geographies

4.9 Other fieldwork based measurements of neighborhood identification, street crossing, street characteristics, views, land uses, barriers, sidewalks, bicycle lanes, mid block crossing, steepness, sidewalk amenities, street trees, buildings, windows, other features of buildings, garages, parking, driveways, maintenance, lighting, freeways, traffic features, architecture/design.

To add in subsequent editions.]

4.10 Distance to Nearest Transit Stop

1. Basic Concept

People walk to transit. The distance to the nearest transit stop may be associated with physical activity.

2. Basic Formula

Distance to Nearest Transit Stop = Network or straight line distance from residence to nearest transit stop.

3. Detailed Formula

As above.

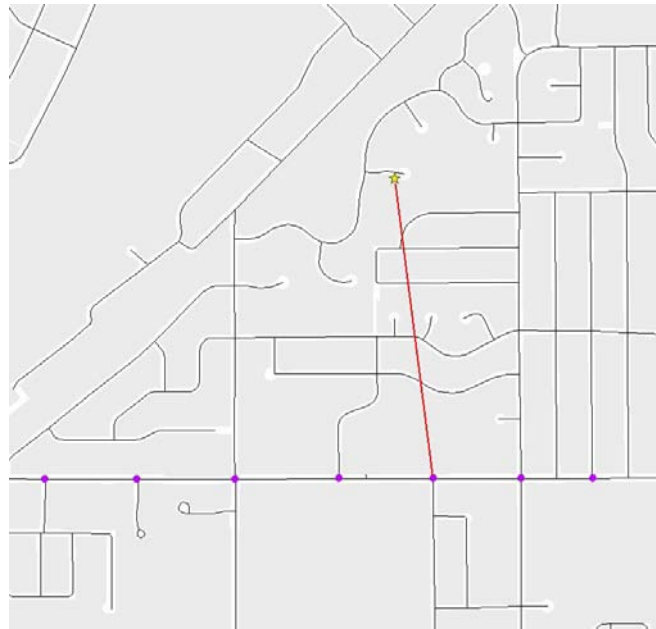
4. Comments and Explanations

This is also done using Network Analyst in ArcView 3.3 (see network buffers above) using a function called Find Closest Facility. You can specify a point layer to use as your “facilities” and then also a point to serve as your origin. It will then take the road network and calculate the shortest path to a “facility” (and it can do this using travel costs as well if, for instance, certain types of roads were considered more or less easy to use).

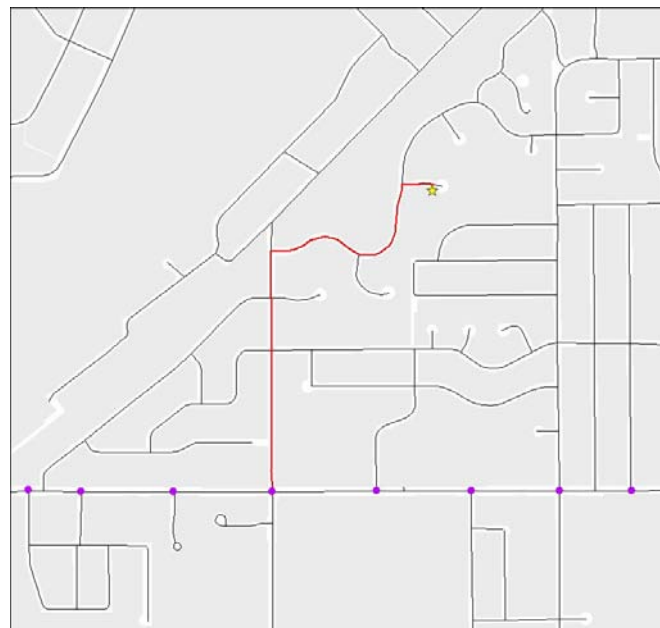
The basic function only works for a limited number of base points (12). In our case we had 715 valid participant addresses so needed to use an ArcView extension called Multiple Closest Facilities. It can be downloaded from the ESRI website at <http://arcscripts.esri.com/details.asp?dbid=13125>. For points that do not fall on the network, there is a dialog box when using this extension that allows the user to decide how far away from the network to search for points to use in the processing. We selected a distance of 250 meters. Points outside that distance will not be used.

5. GIS Approach

The approach for this measure is to load a set of origins (in this case, participant locations) and destinations (transit stops). Then use the Find Closest Facility feature in Network Analyst or the Multiple Closest



Direct line from residence at star in upper part of image to nearest bus stop as the crow flies.



Line along the street network from residence at star in upper part of image to nearest bus stop along the network. Note that it is a different stop to the one in the illustration above.

Facilities extension to calculate the network distance from each origin to the nearest transit stop.

6. GIS Steps

The following procedures were completed using ArcView 3.3.

To complete this protocol you will need:

6. Roads layer (polyline)
7. A participant locations layer (point)
8. A transit stops layer (point)
9. The Network Analyst extension for ArcView
10. The Multiple Closest Facilities extension for ArcView

Calculate network distance to nearest transit stop

14. Start a new ArcView project and create a blank View
 - a. Open the *View* menu and choose *Add Theme*
 - b. Add the roads, participant locations, and transit stops layers to the View
 - c. Open the *View* menu and choose *Properties*
 - d. Make sure the map units (meters, feet, etc.) match the units of the data layers
 - e. Open the *File* menu and choose *Extensions*
 - f. Check the box next to the *Multiple Closest Facilities* extension and click OK
15. Open the *Network Tools* menu that has been added and choose *Multiple closest facilities*
16. In the dialog box that appears, select the participant locations layer in the *From* dropdown box
17. Select the unique ID of the participant locations layer in the *From ID field* dropdown box
18. In the *To* dropdown box, select the transit stops layer
19. Choose the unique ID of the transit stops layer in the *To ID field* dropdown box
20. In the *Network* dropdown box, select the roads layer
21. For *Facilities to find*, enter 1
22. Set the *Cutoff Distance* to 0
23. The *Search Tolerance* is a distance in the current map units that Network Analyst will search away from the road features to find points. Make this number large enough so the process will not miss any of the participant locations
24. Click *Travel to facility*
25. Check the box for *Create Join Table*
26. Hit *Process*

When the process ends, the extension will add a new polyline feature to the View consisting of the network segments that trace the shortest path from each participant location to its nearest transit stop. The table of the new layer contains an *Origin* field with the unique ID of the participant locations layer, a *Destin* field with the unique ID of the closest transit stop, and a *Length* field with the distance in the current map units between the participant location and the closest transit stop.

4.11 Transit Stop Density

1. Basic Concept

Transit stops may also be a proxy for a walkable neighborhood. Transit stop density may correlate with overall activity.

2. Basic Formula

Transit Stop Density= Number of transit stops per unit area.

3. Detailed Formula

As above.

4. Comments and Explanations

None.

5. GIS Approach

The GIS approach is to perform a spatial join between the measurement geographies and the transit stops. This will count the number of stops in each measurement geography. Then divide this number by the net land area of each measurement geography.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0.

To complete this protocol you will need:

1. Site layer (polygon)
2. Transit stops layer (point)
3. Water features layer (polygon)
4. **XTools** extension (available from the Downloads section of the ESRI website)

Refer to Protocol 2.1 for the procedures to calculate net land area (land area with water features removed).

Add the transit stops and site layers to an ArcMap document

1. Right click on the site layer and choose *Joins and Relates*→*Join*
2. Under the dropdown box labeled *What do you want to join to this layer?*, choose *Join data from another layer based on spatial location*
3. In step 1 of the dialog box, choose the transit stops layer
4. In step 2, click the button to choose *Each polygon will be given a summary of the numeric attributes*, etc
5. In step 3, choose a name and location for the output layer
6. Hit OK
7. The output layer now contains a Count field with the number of transit stops found in each feature of the measurement geography

Calculate transit stops per net land area

1. In the Table of Contents, right click on the output layer from the spatial join performed above and choose *Joins and Relates*→*Join*
2. In the dropdown box, choose to Join attributes from a table
3. In step 1, choose to base the join on the field containing the unique ID of the measurement geographies
4. In step 2, load the table from the result of following Protocol 2.1, Net Land Area
5. In step 3, choose the field in the net land area layer's table containing the unique ID of the measurement geographies
6. Hit OK
7. Open the Attribute Table of the output layer from the spatial join, which now has the net land area table joined into it
8. Click *Options* and choose *Add Field*
9. Name the field StopDens or similar, and set it to be type Double
10. Right click on the new field and choose *Calculate Values*
11. In the Field Calculator dialog box, double click the Count field, then click the / button, and finally double click the name of the field containing the net land area
12. Click OK

This field now contains the density of transit stops (number of transit stops divided by the net land area in whichever units you used).

The following variables are not proposed to be used in the study, so only a detailed formula is included.

4.12 Percentage of Blocks with Full Length Sidewalks

Detailed Formula

Percentage of Blocks with Full Length Sidewalks = Percentage of block faces that have a sidewalk along the entire length of at least one side without gaps (see related measure in Cervero and Kockelman 1996, 8).

4.13 Percentage of Blocks with Street Lights

Detailed Formula

Percentage of Blocks with Street Lights = Percentage of block faces that have at least one street light. This will involve creating some kind of logical formula to capture this (see related measure in Cervero and Kockelman 1996, 8, 16).

5. LAND USE MIX

Chapter by: Ann Forsyth (drafting, conceptual issues and formulae, some comments and GIS approach text) and Jason Zimmerman (GIS Steps, many comments/GIS approach text). Reference to additional materials by the team of Active Living Research grantees at the University of North Carolina, led by Daniel Rodriguez.

In Version 2.1 compared with Version 2.0 the basic outlines of several new protocols were added. These include: 5.8, 5.9, 5.10, 5.15. Significant changes were made to 5.13 and 5.14. An error was corrected in 5.6 (now similar land uses = 0 in both 5.6 and 5.7). In version 2.2, the dissimilarity variables were significantly elaborated, and the “North Carolina” variables were also expanded. In version 2.3 the “North Carolina” variables were clarified.

Background

Mixed use is a measure of different activities. However, as Grant (2002) outlines “mixed-use” is often used to indicate a mix of housing types e.g. detached houses and apartments. Transportation planning is in part based on the insight that people move to go between different activities or different destinations.

It is proposed that certain kinds of mixed land uses are particularly important, particularly ones that can provide:

- A greater variety of attractive destinations within walking distance. However, this raises a number of issues: is variety or attractiveness key? Once a critical mass of land use variety has been reached, will more mix make a difference (Krizek 2003 a, b)? In measurement there has been a focus on commercial destinations but other destinations are important also: schools, faith-based facilities, or parks (Audirac 1999).
- More visual variety and interest for pedestrians. Varied land uses are seen as promoting architectural and landscape variety.
- Greater street safety due to informal policing -- one is less likely to be alone with an attacker. This assumes that uses have a mixture of opening hours, particularly in the evening, and generate pedestrian traffic. However, some uses may be perceived to undermine safety—e.g. rowdy bars.

Measures of mixed use have typically been either quite broad—looking at any mix—or have focused on retail destinations. However, other destinations are potentially important such as parks and civic uses. As Krizek (2003a, b) outlines common measures have included:

- Field observations or self report—simple reports on whether mix is present.
- Density and distance measures including of total employment or businesses; density of specific kinds of land uses, businesses and jobs; or distances to particular kinds of businesses (e.g. Cervero and Gorham 1995, Handy 1992).
- Entropy and dissimilarity indices that measure overall mix (e.g. Frank and Pivo 1994; Cervero and Kockelman 1996, 1997).

The now fairly wide availability of parcel level land use data allows other measurements based on particular kinds of land uses (see McNally and Kulkarni 1997, 109; Crane and Crepeau 1998).

Several different sorts of data are used in mixed use measures. Land use data shows how land is actually used at the parcel level. This is distinct from the zoning for a parcel which is what is allowed to be built in the future. Employment data can indicate establishments and is useful in

determining the scale of economic activity. However, it is less useful for ascertaining the presence of some destinations such as parks..

5.1 Percentage of Total Parcel Area in Major Land Uses (seven land uses in this case)

1. Basic Concept

A simple measure of land use percent in major uses. This is less a measure of mix per se than the relative amount of each land use: residential, commercial, office, industrial, institutional, park and recreation, vacant.

The next draft of these protocols will review earlier work that has used similar measures e.g. McNally and Kulkarni (1997, 109) examined a ratio of commercial area to total area.

2. Basic Formula

Percentage of Total Parcel Area in Major Land Uses = Total area in each of seven major land use categories (residential, commercial, office, industrial, institutional, park and recreation, vacant) divided by total land area in parcels.

3. Detailed Formula

Percentage of Total Parcel Area in Major Land Uses = Total area in parcels in each of the seven major land use categories (residential, commercial, office, industrial, institutional, park and recreation, vacant) divided by total land area in parcels, with water area removed. Note that some land uses (agricultural, airport, non-roadbed right-of-way) are not included in our seven major land use categories but are included in the total land area figures.



Parcels coded with the seven major land use categories (residential – yellow; commercial – red; tax exempt – purple; office – blue; park and recreation – green; industrial – dark grey; Vacant not marked).

4. Comments and Explanations

Land uses were assigned at the parcel level and reflected the most detailed data available. These data were then generalized to our seven major land use categories.

Complicating factors may, however, be unique to our data :

- a. Two different water layers were used for exclusions (see earlier discussion in chapter 1)
- b. We used two methods for assigning land uses, depending on if the parcels were in our original Context Areas or if they fell within our extended buffer areas (see Appendix 5C for details on how this was done)
- c. In general we field-checked in the context areas and where large buffers fell outside the context areas we felt that the errors from using Metropolitan Council data would not be so large

5. GIS Approach

The parcel layer (with areas of water removed) was intersected with the measurement geographies and the areas of the parcels recalculated to account for those that were split by the study site boundaries. The land uses associated with each parcel were generalized into seven major land use categories. For each study site, the total area of each land use category was summarized. The percentages of the total parcel area for each study site were then calculated.

6. GIS Steps

[Future versions will update for buffer-related steps and refer to Appendix 5C for details on creating Context Area land uses]

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

4. Site layer (polygon)
5. Land use parcel layer (polygon)
6. **XTools** extension (available from the Downloads section of the ESRI website)

The basic steps are:

- *Determine Net Land Area (without water) for each Site*
- *Intersect Parcels with Site Layer*
- *Convert Land Uses into 7 Categories*
- *Summarize Land Use Hectares for each Site*
- *Calculate Land Use Percentages for each Site*

Determine Net Land Area (without water) for each Site:

2. Follow the steps outlined in the protocol above.

Intersect Parcels with Site Layer:

5. If the site layer does not have unique IDs or names for each site, create them now.
6. Using the GeoProcessing Wizard, intersect the land use parcel layer with the new (net area) site polygon layer
 - g. Under the Tools menu, select “GeoProcessing Wizard”.
 - h. Select “Intersect two layers” and click on “Next”.
 - i. Under “Select the input layer to intersect:” choose your land use parcel layer.
 - j. Under “Select a polygon clip layer:” choose your site layer.

- k. Give your file a name and hit "Finish".
- l. The parcels will now be clipped to the study site boundaries, have areas of water removed, and be assigned the IDs associated with each study site. Note that parcels that exist in two or more overlapping study sites will now be represented by two or more identical (except for ID number) rows in the attribute table).
7. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - e. Under "Select layer to measure", select your new land use parcel layer
 - f. Under "Desired output units", choose your units (depending on the parcel size, try *Meters* or *Feet*, for example)
 - g. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - h. Hit "OK"
8. New fields called "Area" and "Hectares" will be created in the attribute table of your new land use parcel layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

Convert Land Uses into 7 Categories:

1. Open the attribute table for the land use parcels.
2. Click on the "Options" button and select "Add Field...".
3. Create a field called 7LUC that is type "Text".
4. Reclassify your parcels so that the land uses are generalized into the 7 major land use categories (residential, commercial, office, industrial, institutional, park and recreation, vacant). How this is done depends on the level of detail of your existing land use categories – for example, if you have Small-scale Commercial, Strip Commercial, and Shopping Center land uses, these would all be generalized to a new land use code of Commercial.
5. Enter the new land use codes in the 7LUC field.

Summarize Land Use Hectares for each Site:

1. Right click on the land use parcel layer and select "Properties".
2. Click the "Definition Query" tab and click the "Query Builder" button.
3. In the "SELECT * FROM . . . WHERE:" box select the parcels that are one of the new generalized land use categories.
4. Click "OK" then click "Apply". Now, only parcels in the 7 major land use categories will be shown in the attribute table.
5. Under the XTools drop-down menu, select "Table Operations" and "Export to Excel".
6. Select your land use parcel layer and the following three fields: ID, Hectares, and 7LUC.
7. Click "OK". Depending on the number of parcels you have selected, it may take some time to export the data to Excel.
8. The new Excel file will contain the hectares of the land uses in each study site; use Excel's Subtotals command (under the Data drop-down menu) to summarize and group this information.
9. Re-query the land use parcel layer to once again include all parcels (do not include areas of water or roads). Follow steps 3-6 but modify the criteria for the parcels to be selected.
10. Return to the land use parcel attribute table.
11. Right-click on the field that contains the IDs and select Summarize.
12. Under "2. Choose one or more summary statistics..." expand the box labeled "Hectares" and check the box marked "Sum".
13. Select or create an output file name and hit OK.
14. The output .dbf file will contain the total hectares of the land use in each study site.

Calculate Land Use Percentages for each Site:

1. In Excel or other spreadsheet program, combine the land use hectares and your total parcel hectares based on the site ID numbers.
2. For each land use category in each site, divide the land use hectares by total parcel hectares to get the percentages of total parcel area in the 7 major land use categories.

5.2 Percentage of Land Area in Night Time Uses

1. Basic Concept

Part of the benefit of mixed use is thought to be the increased activity that it provides at various times of the day and night. This increases safety and increases the time period in which destinations are available to give a reason for walking.

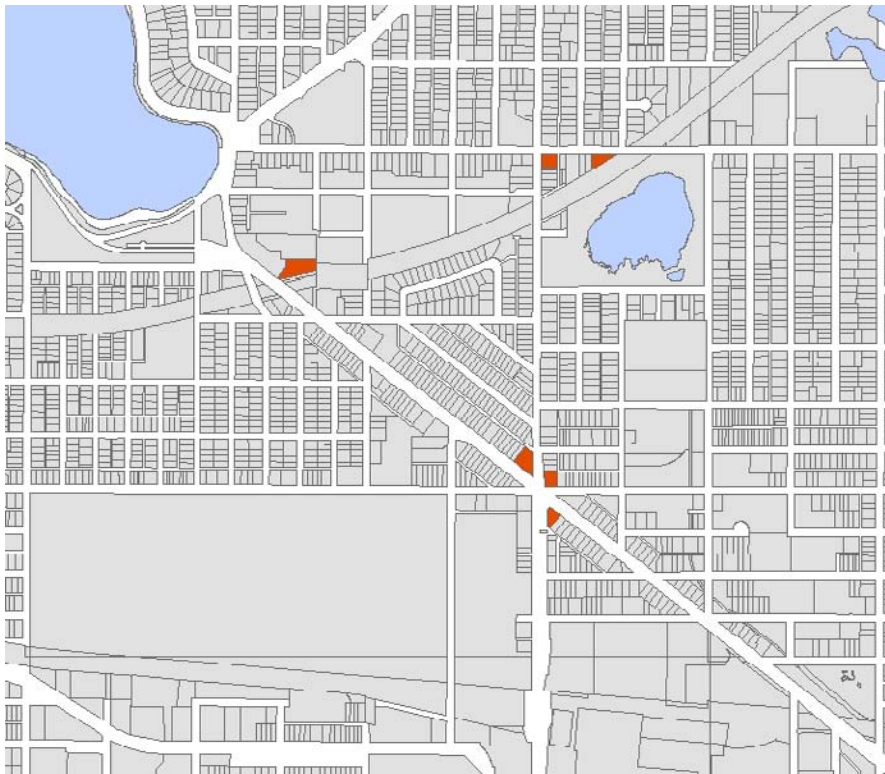
2. Basic Formula

Percentage of Land Area in Night Time Uses = Total area in parcels with Night Time Uses divided by total land area in parcels.

3. Detailed Formula

Percentage of Land Area in Night Time Uses = Total area in parcels with Night Time Uses divided by total land area in parcels with water area removed. The specific uses classed as night time are the following, in terms of Ramsey County uses:

- a. HOTELS
- b. SUPERMARKETS
- c. RESTURANT, CAFETERIA, AND/OR BAR
- d. CONVENIENCE STORE
- e. THEATERS



Parcels with Night Time Uses highlighted.

4. Comments and Explanations

Ramsey County parcels included detailed land use codes. Parcels outside of Ramsey County were field checked to populate a land use data field with the same level of detail.

5. GIS Approach

Using the parcel layer that was intersected with the study sites (from above), the parcels with Night Time Uses were selected. For each study site, the total hectares of the parcels with Night Time Uses were summarized. The percentages of the land area in Night Time Uses for each study site were then calculated.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

1. Net area land use parcel layer (polygon) created above
2. **XTools** extension (available from the Downloads section of the ESRI website)

The basic steps are:

- *Select Parcels with Night Time Uses*
- *Summarize Land Use Hectares for each Site*
- *Calculate Land Use Percentages for each Site*

Select Parcels with Night Time Uses:

2. Open the attribute table for the land use parcels.
3. Click on the "Options" button and select "Add Field...".
4. Create a field called NIGHT that is type "Text".
5. Select any parcels that qualify as "Night Time Uses". The following are the uses we selected:
 - a. HOTELS
 - b. SUPERMARKETS
 - c. RESTURANT, CAFETERIA, AND/OR BAR
 - d. CONVENIENCE STORE
 - e. THEATERS
6. Enter a new land use code in the NIGHT field.

Summarize Land Use Hectares for each Site:

1. Right click on the land use parcel layer and select "Properties".
2. Click the "Definition Query" tab and click the "Query Builder" button.
3. In the "SELECT * FROM . . . WHERE:" box select the parcels that are night time uses.
4. Click "OK" then click "Apply". Now, only parcels that are night time uses will be shown in the attribute table.
5. Under the XTools drop-down menu, select "Table Operations" and "Export to Excel".
6. Select your land use parcel layer and the ID and Hectares fields.
7. Click "OK". Depending on the number of parcels you have selected, it may take some time to export the data to Excel.
8. The new Excel file will contain the hectares of the night time uses in each study site; use Excel's Subtotals command (under the Data drop-down menu) to summarize and group this information.
9. Re-query the land use parcel layer to once again include all parcels (do not include areas of water or roads). Follow steps 1-4 but modify the criteria for the parcels to be selected.
10. Return to the land use parcel attribute table.
11. Right-click on the field that contains the IDs and select Summarize.
12. Under "2. Choose one or more summary statistics..." expand the box labeled "Hectares" and check the box marked "Sum".
13. Select or create an output file name and hit OK.
14. The output .dbf file will contain the total hectares of the land use in each study site.

Calculate Land Use Percentages for each Site:

1. In Excel or other spreadsheet program, combine the land use hectares and your total parcel hectares based on the site ID numbers.
2. For each land use category in each site, divide the land use hectares by total parcel hectares to get the percentages of total parcel area in the night time uses.

5.3 Percentage of Land Area in Social Uses

1. *Basic Concept*

Land uses that perform a social or civic function may be important destinations for walking. These are often missed in measures of mixed use that focus on retail and other commercial uses.

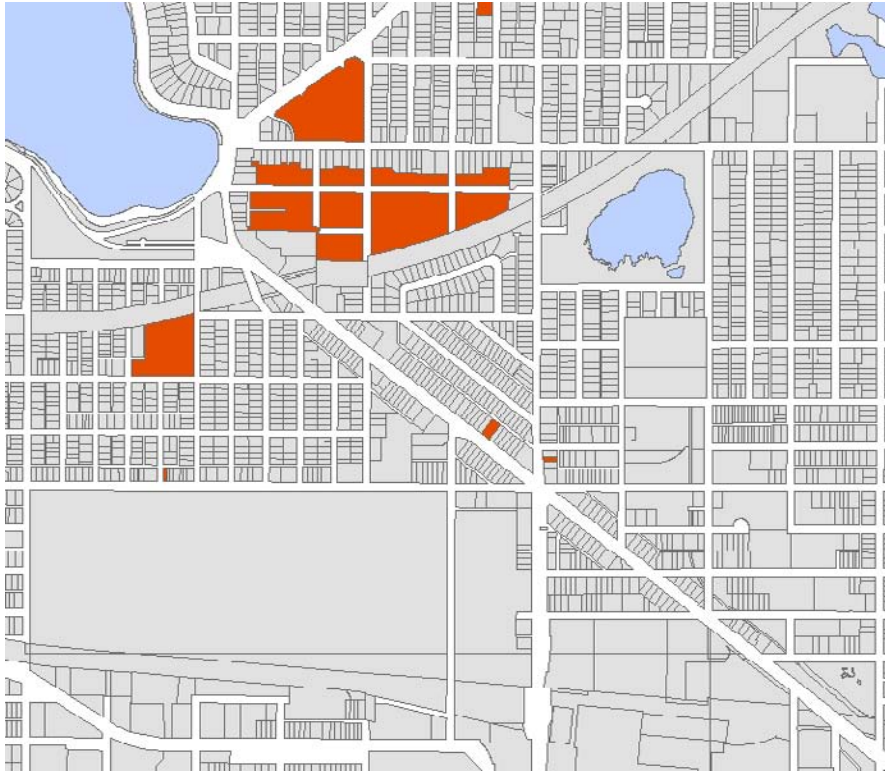
2. *Basic Formula*

Percentage of Land Area in Social Uses = Total area in parcels with Social Uses divided by total land area in parcels.

3. *Detailed Formula*

Percentage of Land Area in Social Uses = Total area in parcels with Social Uses divided by total land area in parcels with water area removed. Social uses include the following Ramsey County uses:

- a. DAY CARE CENTERS
- b. MEDICAL CLINICS AND OFFICES
- c. THEATERS
- d. BOWLING ALLEYS
- e. LODGE HALLS AND AMUSEMENT PARKS
- f. SPORT/PUBLIC ASSEMBLY FACILITY
- g. EXEMPT COMMUNITY RECREATIONAL FAC.
- h. LIBRARY
- i. EXEMPT PROPERTY OWNED BY BD OF EDUC.
- j. EXEMPT PROP OWNED BY PRIVATE SCHOOLS
- k. CHURCHES ETC PUBLIC WORSHIP PRIVE



Parcels with social uses highlighted.

4. Comments and Explanations

Ramsey County parcels included detailed land use codes. Parcels outside of Ramsey County were field checked to populate a land use data field with the same level of detail.

5. GIS Approach

Using the parcel layer that was intersected with the study sites (from above), the parcels with Social Uses were selected. For each study site, the total hectares of the parcels with Social Uses were summarized. The percentages of the land area in Social Uses for each study site were then calculated.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

1. Net area land use parcel layer (polygon) created above
2. **XTools** extension (available from the Downloads section of the ESRI website)

The basic steps are:

- *Select Parcels with Social Uses*
- *Summarize Land Use Hectares for each Site*
- *Calculate Land Use Percentages for each Site*

Select Parcels with Social Uses:

1. Open the attribute table for the land use parcels.
2. Click on the "Options" button and select "Add Field...".
3. Create a field called SOCIAL that is type "Text".

4. Select any parcels that qualify as “Social Uses”. The following are the uses we selected:
 - l. DAY CARE CENTERS
 - m. MEDICAL CLINICS AND OFFICES
 - n. THEATERS
 - o. BOWLING ALLEYS
 - p. LODGE HALLS AND AMUSEMENT PARKS
 - q. SPORT/PUBLIC ASSEMBLY FACILITY
 - r. EXEMPT COMMUNITY RECREATIONAL FAC.
 - s. LIBRARY
 - t. EXEMPT PROPERTY OWNED BY BD OF EDUC.
 - u. EXEMPT PROP OWNED BY PRIVATE SCHOOLS
 - v. CHURCHES ETC PUBLIC WORSHIP PRIVE
5. Enter a new land use code in the SOCIAL field.

Summarize Land Use Hectares for each Site:

1. Right click on the land use parcel layer and select “Properties”.
2. Click the “Definition Query” tab and click the “Query Builder” button.
3. In the “SELECT * FROM . . . WHERE:” box select the parcels that are social uses.
4. Click “OK” then click “Apply”. Now, only parcels that are social uses will be shown in the attribute table.
5. Under the XTools drop-down menu, select “Table Operations” and “Export to Excel”.
6. Select your land use parcel layer and the ID and Hectares fields.
7. Click “OK”. Depending on the number of parcels you have selected, it may take some time to export the data to Excel.
8. The new Excel file will contain the hectares of the social uses in each study site; use Excel’s Subtotals command (under the Data drop-down menu) to summarize and group this information.
9. Re-query the land use parcel layer to once again include all parcels (do not include areas of water or roads). Follow steps 1-4 but modify the criteria for the parcels to be selected.
10. Return to the land use parcel attribute table.
11. Right-click on the field that contains the IDs and select Summarize.
12. Under “2. Choose one or more summary statistics...” expand the box labeled “Hectares” and check the box marked “Sum”.
13. Select or create an output file name and hit OK.
14. The output .dbf file will contain the total hectares of the land use in each study site.

Calculate Land Use Percentages for each Site:

1. In Excel or other spreadsheet program, combine the land use hectares and your total parcel hectares based on the site ID numbers.
2. For each land use category in each site, divide the land use hectares by total parcel hectares to get the percentages of total parcel area in the social uses.

5.4 Percentage of Land Area in Retail Uses

1. Basic Concept

Retail uses are an important destination for trips. These protocols use a number of different retail measures including land use (this protocol) and employment data (see below).

A later version of these protocols will deal with how retail measures have been used in previous studies e.g. Crane and Crepeau (1998, 26) who examined the share of each census tract in commercial use and Cervero and Kockelman (1996, 8) who looked at retail uses per developed hectare.

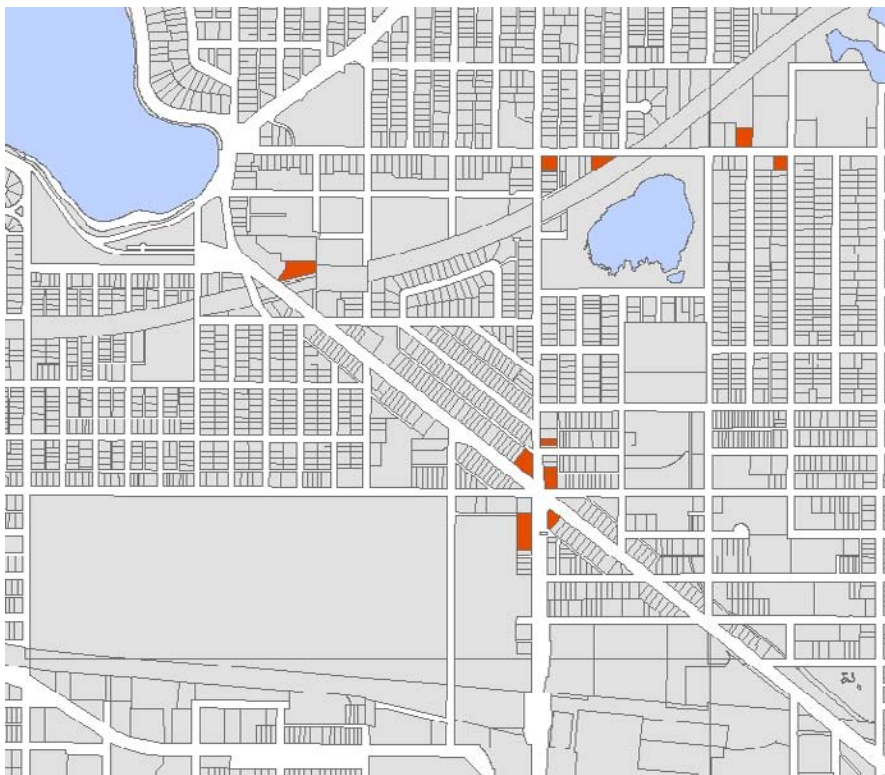
2. Basic Formula

Percentage of Land Area in Retail Uses = Total area in parcels with Retail Uses divided by total land area in parcels.

3. Detailed Formula

Percentage of Land Area in Retail Uses = Total area in parcels with Retail Uses divided by total land area in parcels with water area removed. Retail uses include the following Ramsey County uses:

- a. SMALL (UNDER 10,000SF) DETACH RETAI
- b. SUPERMARKETS
- c. DISCOUNT STORES & JR. DEPT STORES
- d. MEDIUM DETACHED RETAIL
- e. FULL LINE DEPARTMENT STORES
- f. NEIGHBORHOOD SHOPPING CENTER
- g. COMMUNITY SHOPPING CENTER
- h. RESTURANT, CAFETERIA, AND/OR BAR
- i. SMALL STRIP CENTER
- j. CONVENIENCE STORE
- k. FULL SERVICE BANKS



Parcels with retail uses highlighted.

4. Comments and Explanations

Ramsey County parcels included detailed land use codes. Parcels outside of Ramsey County were field checked to populate a land use data field with the same level of detail.

5. GIS Approach

Using the parcel layer that was intersected with the study sites (from above), the parcels with Retail Uses were selected. For each study site, the total hectares of the parcels with Retail Uses were summarized. The percentages of the land area in Retail Uses for each study site were then calculated.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

1. Net area land use parcel layer (polygon) created above
2. **XTools** extension (available from the Downloads section of the ESRI website)

The basic steps are:

- *Select Parcels with Retail Uses*
- *Summarize Land Use Hectares for each Site*
- *Calculate Land Use Percentages for each Site*

Select Parcels with Retail Uses:

1. Open the attribute table for the land use parcels.
2. Click on the "Options" button and select "Add Field...".
3. Create a field called RETAIL that is type "Text".
4. Select any parcels that qualify as "Retail Uses". The following are the uses we selected:
 - l. SMALL (UNDER 10,000SF) DETACH RETAI
 - m. SUPERMARKETS
 - n. DISCOUNT STORES & JR. DEPT STORES
 - o. MEDIUM DETACHED RETAIL
 - p. FULL LINE DEPARTMENT STORES
 - q. NEIGHBORHOOD SHOPPING CENTER
 - r. COMMUNITY SHOPPING CENTER
 - s. RESTURANT, CAFETERIA, AND/OR BAR
 - t. SMALL STRIP CENTER
 - u. CONVENIENCE STORE
 - v. FULL SERVICE BANKS
5. Enter a new land use code in the RETAIL field.

Summarize Land Use Hectares for each Site:

1. Right click on the land use parcel layer and select "Properties".
2. Click the "Definition Query" tab and click the "Query Builder" button.
3. In the "SELECT * FROM . . . WHERE:" box select the parcels that are retail uses.
4. Click "OK" then click "Apply". Now, only parcels that are retail uses will be shown in the attribute table.
5. Under the XTools drop-down menu, select "Table Operations" and "Export to Excel".
6. Select your land use parcel layer and the ID and Hectares fields.
7. Click "OK". Depending on the number of parcels you have selected, it may take some time to export the data to Excel.
8. The new Excel file will contain the hectares of the social uses in each study site; use Excel's Subtotals command (under the Data drop-down menu) to summarize and group this information.
9. Re-query the land use parcel layer to once again include all parcels (do not include areas of water or roads). Follow steps 1-4 but modify the criteria for the parcels to be selected.
10. Return to the land use parcel attribute table.
11. Right-click on the field that contains the IDs and select Summarize.

12. Under “2. Choose one or more summary statistics...” expand the box labeled “Hectares” and check the box marked “Sum”.
13. Select or create an output file name and hit OK.
14. The output .dbf file will contain the total hectares of the land use in each study site.

Calculate Land Use Percentages for each Site:

1. In Excel or other spreadsheet program, combine the land use hectares and your total parcel hectares based on the site ID numbers.
2. For each land use category in each site, divide the land use hectares by total parcel hectares to get the percentages of total parcel area in the retail uses.

5.5 Percentage of Land Area in Industrial and Auto-Oriented Uses

1. Basic Concept

Industrial and auto-oriented land uses are thought to deter walking.

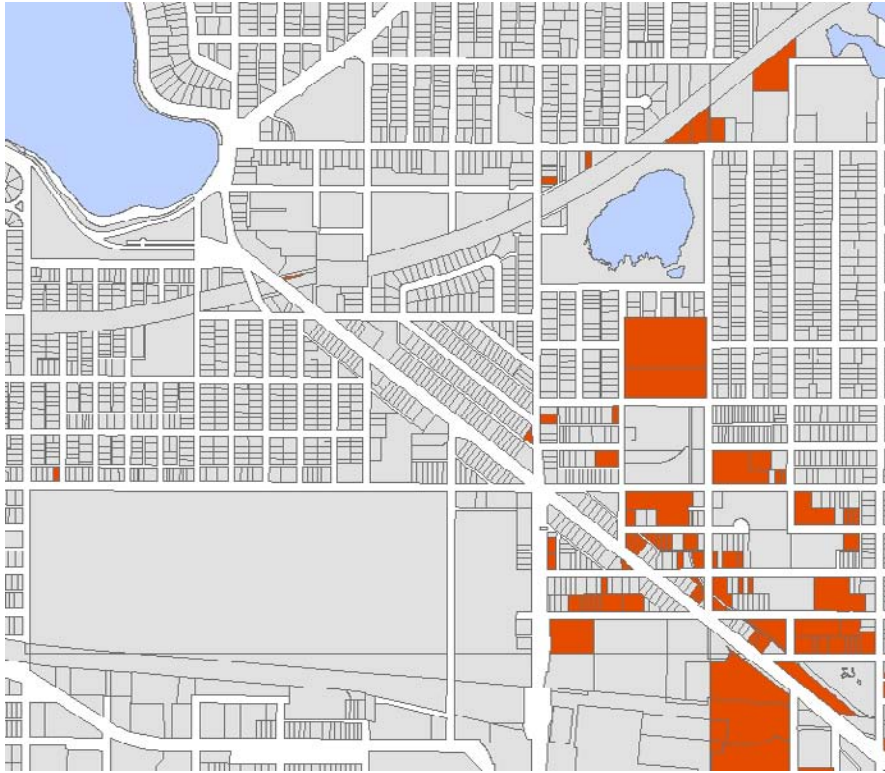
2. Basic Formula

Percentage of Land Area in Industrial and Auto-Oriented Uses = Total area in parcels with Industrial and Auto-Oriented Uses divided by total land area in parcels.

3. Detailed Formula

Percentage of Land Area in Industrial and Auto-Oriented Uses = Total area in parcels with Industrial and Auto-Oriented Uses divided by total land area in parcels with water area removed. Industrial uses include the following Ramsey County uses:

- a. INDUSTRIAL, VACANT LAND
- b. FOOD&DRINK PROCESS PLANTS AND STORAE
- c. FOUNDERIES&HEAVY MANUFACT PLANTS
- d. MANUFACTURING & ASSEMBLY LIGHT
- e. GRAIN ELEVATORS
- f. OTHER INDUSTRIAL STRUCTURES
- g. CAR WASHES
- h. AUTO CAR SALES AND SERVICES
- i. PARKING GARAGE STRUCTURE & LOTS
- j. FLEX INDUSTRAIL CENTER
- k. COMMERCIAL WAREHOUSES
- l. MINI WAREHOUSE
- m. COMMERCIAL TRUCK TERMINALS
- n. RAILROAD REAL PROP USED IN OPERATION



Parcels with industrial and auto-oriented uses highlighted.

4. Comments and Explanations

Ramsey County parcels included detailed land use codes. Parcels outside of Ramsey County were field checked to populate a land use data field with the same level of detail.

5. GIS Approach

Using the parcel layer that was intersected with the study sites (from above), the parcels with Industrial and Auto-Oriented Uses were selected. For each study site, the total hectares of the parcels with Industrial and Auto-Oriented Uses were summarized. The percentages of the land area in Industrial and Auto-Oriented Uses for each study site were then calculated.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

1. Net area land use parcel layer (polygon) created above
2. **XTools** extension (available from the Downloads section of the ESRI website)

The basic steps are:

- *Select Parcels with Industrial and Auto-Oriented Uses*
- *Summarize Land Use Hectares for each Site*
- *Calculate Land Use Percentages for each Site*

Select Parcels with Industrial and Auto-Oriented Uses:

1. Open the attribute table for the land use parcels.
2. Click on the "Options" button and select "Add Field...".
3. Create a field called AUTO that is type "Text".

4. Select any parcels that qualify as “Industrial and Auto-Oriented Uses”. The following are the uses we selected:
 - o. INDUSTRIAL, VACANT LAND
 - p. FOOD&DRINK PROCESS PLANTS AND STORAE
 - q. FOUNDERIES&HEAVY MANUFACT PLANTS
 - r. MANUFACTURING & ASSEMBLY LIGHT
 - s. GRAIN ELEVATORS
 - t. OTHER INDUSTRIAL STRUCTURES
 - u. CAR WASHES
 - v. AUTO CAR SALES AND SERVICES
 - w. PARKING GARAGE STRUCTURE & LOTS
 - x. FLEX INDUSTRAIL CENTER
 - y. COMMERCIAL WAREHOUSES
 - z. MINI WAREHOUSE
 - aa. COMMERCIAL TRUCK TERMINALS
 - bb. RAILROAD REAL PROP USED IN OPERATION
5. Enter a new land use code in the AUTO field.

Summarize Land Use Hectares for each Site:

1. Right click on the land use parcel layer and select “Properties”.
2. Click the “Definition Query” tab and click the “Query Builder” button.
3. In the “SELECT * FROM . . . WHERE:” box select the parcels that are industrial and auto-oriented uses.
4. Click “OK” then click “Apply”. Now, only parcels that are industrial and auto-oriented uses will be shown in the attribute table.
5. Under the XTools drop-down menu, select “Table Operations” and “Export to Excel”.
6. Select your land use parcel layer and the ID and hectares fields.
7. Click “OK”. Depending on the number of parcels you have selected, it may take some time to export the data to Excel.
8. The new Excel file will contain the hectares of the social uses in each study site; use Excel’s Subtotals command (under the Data drop-down menu) to summarize and group this information.
9. Re-query the land use parcel layer to once again include all parcels (do not include areas of water or roads). Follow steps 1-4 but modify the criteria for the parcels to be selected.
10. Return to the land use parcel attribute table.
11. Right-click on the field that contains the IDs and select Summarize.
12. Under “2. Choose one or more summary statistics...” expand the box labeled “Hectares” and check the box marked “Sum”.
13. Select or create an output file name and hit OK.
14. The output .dbf file will contain the total hectares of the land use in each study site.

Calculate Land Use Percentages for each Site:

1. In Excel or other spreadsheet program, combine the land use hectares and your total parcel hectares based on the site ID numbers.
2. For each land use category in each site, divide the land use hectares by total parcel hectares to get the percentages of total parcel area in the industrial and auto-oriented uses.

5.6 Proportion of Dissimilar Land Uses Among Grid Cells by Cell, Formula 1

1. Basic Concept

This measure, adapted from work by Cervero and Kockelman (1996, 8), places a 100*100 meter grid over the study site, assigns a major land use to each grid cell, and then calculates the proportion of dissimilar land uses adjacent to or kitty corner to the central cell. It is a way of standardizing mixed use calculations although initially it seems to have been used because data were already available in the 100 meter cell format. Cervero and Kockelman go on to create an index basically of average dissimilarity across and area such as a tract, similar to the method described below. However, values for individual grid cells are also important.

2. Basic Formula

Proportion of Dissimilar Land Uses Among Grid Cells by Cell = Working from a grid, pick one cell and calculate the dominant land use for that cell, calculate the dominant land uses in the adjacent grid cells, then calculate the percentage of cells with different land uses to the central cell.

3. Detailed Formula

Proportion of Dissimilar Land Uses Among Grid Cells by Cell = Working from a grid such as the one in the diagram below, select one cell and calculate the dominant land use for that cell, calculate the dominant land uses in the adjacent grid cells, then calculate the percentage of cells with land uses different to the central cell. Land uses include the seven major land uses above as well as water and an “other” category for land uses that are not among our seven major land uses (e.g., agricultural, airport). Majority land uses are assigned based on the area within parcels as well as water bodies (road rights-of-way are not included in the calculations).

4. Comments and Explanations

We found two ways to do this.

A. Using a grid to lay over the study areas, measuring land uses, and then calculating the dissimilarity index in Excel.

B. We later found a way to automate the grid measurement process to create a dominant land use, based on Steiner (2004). However, this just allocates a dominant land use and Excel is still needed to perform the dissimilarity.

For both, the land use for a grid cell (see center cell A in the diagram below) is compared to the land uses in each of its 8 neighboring cells (B, C, D, E, F, G, H, and I), scoring 0 for an identical use and 1 for a different use. These 8 values are then averaged to generate the index for that single cell.

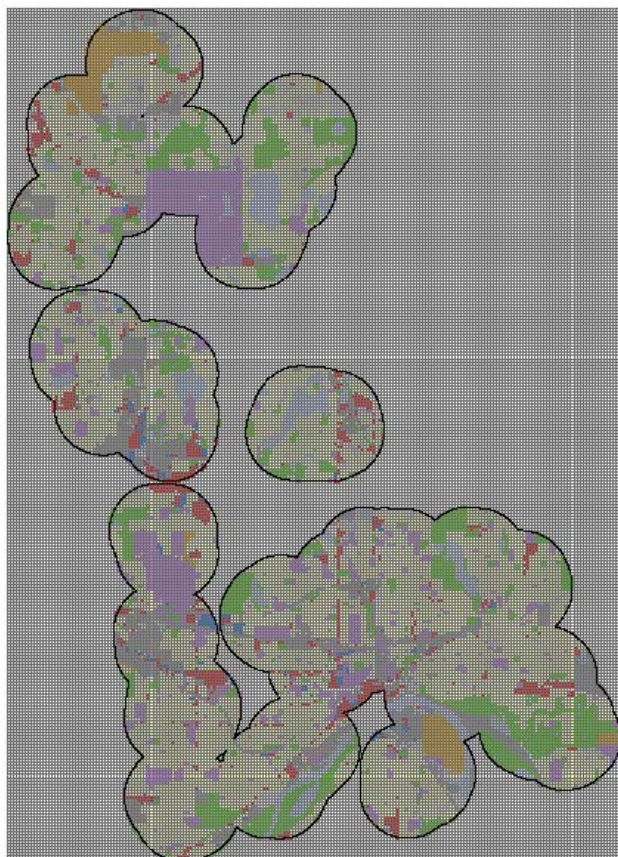
Sample grid cell pattern:

D	F	I
C	A	H
B	E	G

The steps for transferring the land use data for the grid cells to Excel and performing the necessary calculations to generate the dissimilarity indices are complicated. We have attempted to break out the steps to show both a generalization and an actual example from our data.

As part of the GIS steps used to create the grid (outlined below), each grid cell is assigned a unique ID number. These numbers are assigned consecutively, from the bottom left hand corner of the grid to the top right hand corner.

For example, the dissimilarity formula was, in our study, applied to a grid of 207 columns and 287 rows (enough to cover completely our largest buffered areas – see image). Using the steps outlined below, the grid cells were numbered consecutively from bottom to top (rows 1-287) beginning on the left and working to the right (columns 1-207). Since the steps for assigning unique ID numbers produce a beginning number of 0, the leftmost bottom cell was number 0, the leftmost top cell was number 286, the rightmost bottom cell was number 59122, and the rightmost top cell was number 59408 (which is $[207 \times 287] - 1$).



Study area with 100*100 meter grid overlay.

Looking more closely at a handful of grid cells from our study area, the pattern of unique ID numbers becomes more clear (compare to the sample grid cell pattern above).

14714	15001	15288
14713	15000	15287
14712	14999	15286

100*100 meter grid cells with land use coding and unique grid cell ID numbers.

When the data for each cell is exported to Excel (in order to carry out the dissimilarity calculations), each grid cell also assumes an Excel cell reference number. Notice how the cell reference numbers from the image below and the unique ID numbers from the image above are also found in the clipped section of the Excel spreadsheet.

	A6949	A7236	A7523
	A6948	A7235	A7522
	A6947	A7234	A7521

100*100 meter grid cells with land use coding and associated Excel cell reference numbers.

	A	B	C
1	Unique ID	Land Use Code	Dissimilarity Index
...			
6946	14711	I	0.5
6947	14712	I	0.375
6948	14713	I	0.5
6949	14714	R	0.875
6950	14715	WAT	0.5
...			
7231	14996	R	0
7232	14997	R	0.125
7233	14998	R	0.25
7234	14999	R	0.375
7235	15000	R	0.375
7236	15001	PR	1
7237	15002	WAT	0.625
7238	15003	WAT	0.625
7239	15004	I	0.25
...			
7520	15285	R	0
7521	15286	R	0
7522	15287	R	0.125
7523	15288	R	0.5
7524	15289	I	0.625
...			

The spreadsheet that calculates the dissimilarity index for each cell in the 100*100 meter grid uses the following methodology:

1. Column A contains the unique ID number for each grid cell.
2. Column B contains the land use code associated with each grid cell (calculated to be the majority land use in each cell).
3. Column C contains the formula to calculate the dissimilarity index for each cell, utilizing the land use codes from the adjoining 8 grid cells. The formula does the following:
 - a. Checks the unique ID number for that cell
 - b. Calculates the unique ID numbers for the adjoining 8 cells (since the cells are numbered consecutively, these offsets are always the same – in our example, based on the overall size of the grid, to calculate the number of the grid cell to the lower left subtract 288)

	15000	
14712		

- Looks up or down the unique ID column to find the matching ID numbers
- In the row of each matching ID number, compares the land use code to the land use code of the center cell
- If the land use codes match, a value of 0 is returned; if the land use codes do not match, a value of 1 is returned
- The 8 values (0s or 1s) are summed and divided by 8 to get an index number between 0 and 1

In Excel, here is the detailed formula for calculating the Cell by Cell Dissimilarity Index (with values based on our data and being calculated for the cell with unique ID 15000):

```
=SUM(IF(B7235=(VLOOKUP(A7235-288,$A$2:$B$26640,2,FALSE)),0,1),
IF(B7235=(VLOOKUP(A7235-287,$A$2:$B$26640,2,FALSE)),0,1),
IF(B7235=(VLOOKUP(A7235-286,$A$2:$B$26640,2,FALSE)),0,1),
IF(B7235=(VLOOKUP(A7235-1,$A$2:$B$26640,2,FALSE)),0,1),
IF(B7235=(VLOOKUP(A7235+1,$A$2:$B$26640,2,FALSE)),0,1),
IF(B7235=(VLOOKUP(A7235+286,$A$2:$B$26640,2,FALSE)),0,1),
IF(B7235=(VLOOKUP(A7235+287,$A$2:$B$26640,2,FALSE)),0,1),
IF(B7235=(VLOOKUP(A7235+288,$A$2:$B$26640,2,FALSE)),0,1))/8
```

So, generally, for each center cell A,

- SUM(B-I)/8** sums the values returned for B-I and divides the sum of the returned values by 8 to get the dissimilarity index for cell A

where **B-I** are the statements:

- IF(W=(Y),0,1)** which check to see if the land use values of the 8 adjoining cells are the same as that of cell A

where **W** is:

- the land use value of cell A

where **Y** is the statement:

- VLOOKUP(Z,range,column,FALSE)** which looks up data in a specified cell according to set of rules (the V in VLOOKUP indicates that Excel will be searching vertically in the spreadsheet in contrast to an HLOOKUP which searches horizontally)

where **Z** is the series of statements:

- V-offset1; V-offset2; V-offset3; V-offset4; V+offset4; V+offset3; V+offset2; V+offset1

where **V** is:

- the unique numerical identifier of cell A, adjusted in each of the 8 entries to jump up or down the spreadsheet to access the land use data associated with each of the 8 adjoining cells of cell A (here, based on our grid size, the offsets are 288, 287, 286, and 1)

and **range** is:

- the extent of the data in the worksheet (here, from cell A2 to cell B26640 – the area that contains the data on both the unique ID numbers and the land use codes)

and **column** is:

- the column from which the comparison value is to be selected (here, column 2, which contains the land use codes)

and **FALSE** is:

- the command that forces VLOOKUP to search for an exact match.

and **0,1**:

- returns a value of 0 if W matches Y and returns 1 if it does not.

So from our example above we see that cell A with unique ID number 15000 has a land use code R (for Residential). It is surrounded by cells with land uses I, I, R, R, PR, R, R, and R. The dissimilarity formula will return values of 1, 1, 0, 0, 1, 0, 0, and 0. Summing these eight values and dividing by eight yields a dissimilarity index for cell A of 0.375.

We did find one “glitch” in the way we used the MAJORITY function to calculate the dominant land use in each cell. Since our land use layer was parcel based and did not include polygons for road rights-of-way, when the MAJORITY function was used it only counted area that was within our data layer. Therefore, a 100*100 meter grid cell that was 95% road right-of-way and 5% residential land use (such as a cell located in the middle of a large highway) would be coded as residential. The result is dissimilarity data that indicates less variety (or more similarity) of land uses than actually exists along these wide road right-of-ways.

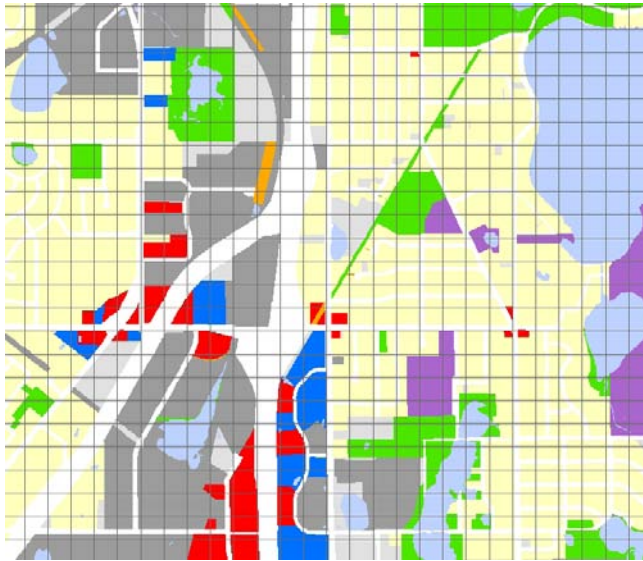
A fix to this problem would be to “fill” the road rights-of-way with an additional polygon layer and take these areas into account (much like how water bodies are handled). After discussing the issue we decided not to take this step and continue using the data as it was originally calculated. By taking these road rights-of-way into account, we would be adding dissimilarity into our results, but it would be based on wide road rights-of-way that are not pedestrian friendly instead of a mix of land uses which are suggested to support pedestrian activity. Therefore adding a road right-of-way layer would actually be working against our study goals.

Also, it should be noted that the Convert to Raster function used to change the land use parcel layer into a 10*10 meter grid cell raster does NOT use a MAJORITY function to calculate the underlying land use. In fact, it simply takes the land use beneath the grid cell centerpoint and

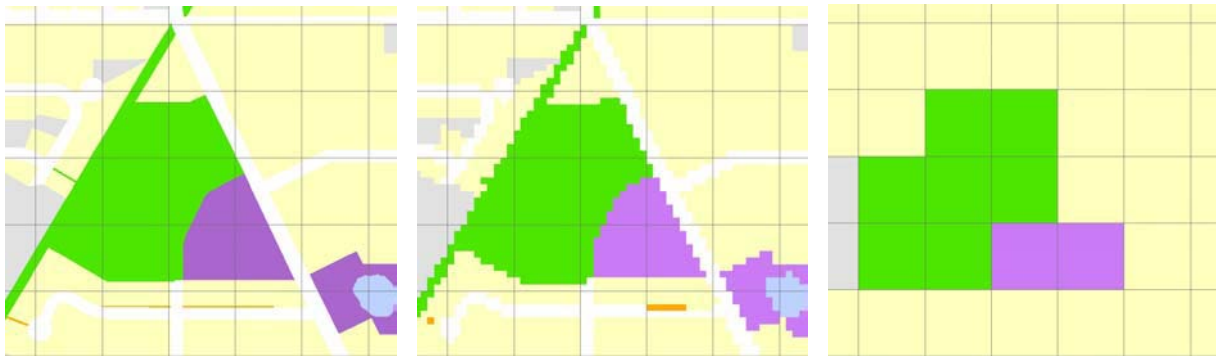
assigns it to the grid cell. Although this step results in some cells that misrepresent the true nature of the underlying land uses, we devised a method that broke the 100*100 meter grid cells into 10*10 meter grid cells, took the land use under the center point, and then used that as the basis for the majority land use. We estimated that this should remove most, if not all, of this variation.

The following images demonstrate the cell by cell dissimilarity index in one study site.

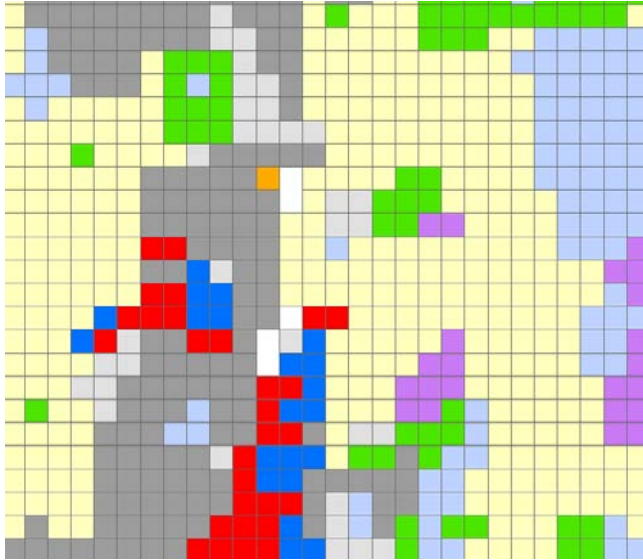
The first shows the land uses as defined by the parcel boundaries (with the 100*100 meter grid cell overlay).



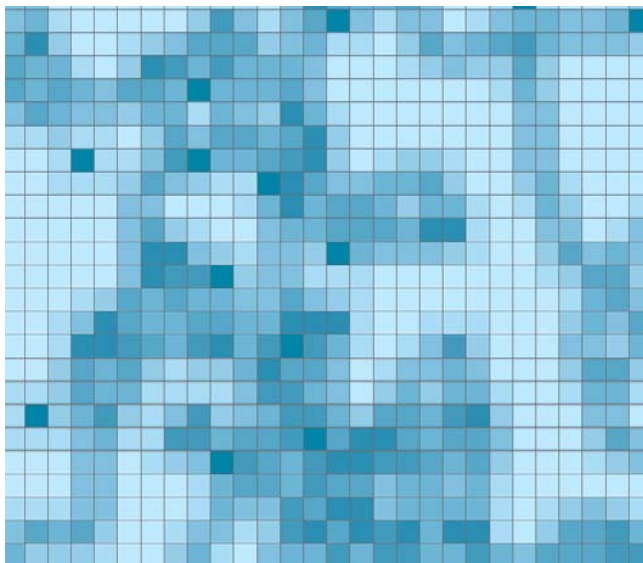
The next set of three images shows a close-up of the transition of land use designations from parcels to 10*10 meter grid cells to 100*100 meter grid cells.



The next image shows the land uses in the broader context as defined by the 100*100 meter grid cell boundaries with the dominant land uses applied.



The last shows the cell by cell dissimilarity index. The index ranges from 0 – low dissimilarity (the lightest shade of blue, where the dominant land use of the cell is the same as all of the dominant land uses of the eight adjacent cells) to 1 – high dissimilarity (the darkest shade of blue, where the dominant land use of the cell is different from any of the dominant land uses of the eight adjacent cells).



5. GIS Approach

The basic steps to calculate the level of difference between each cell and its eight neighbors are:

1. Use FISHNET tool to create a 100*100 meter raster grid of the land use data that aligns with the left and bottom edges of the data
2. Create a raster of the land use data in a 10*10 meter grid (this should align with the 100*100 meter grid)

3. Create unique ID numbers for the 100*100 meter grid (copy the existing the Object_ID into a new field)
4. Use the Zonal Statistics tool to calculate the MAJORITY of land uses for each 100*100 meter grid cell of the 100 10*10 meter raster cells contained in each (this creates a raster)
5. Convert the raster back into polygons (don't simplify the polygons!)
6. Create centroids for the original 100*100 meter grid
7. Assign the underlying (majority) land uses to the centroids using a spatial join
8. Assign the centroid land uses back to the 100*100 meter grid
9. Export (using XTools) the unique ID numbers and the land use codes to Excel
10. Plug in the dissimilarity formula to produce the dissimilarity index for each cell
11. Save the unique ID number and the index columns in dbf format
12. Join the newly indexed dbf file to the 100*100 meter grid cell file
13. Create a new field for the dissimilarity numbers and copy the indexed column before removing the join
14. Join this data to the participant point file (using a spatial join) to be able to produce dissimilarity indices for each of the participants (there may be some index numbers that will be repeated since some 100*100 meter grid cells may contain more than one participant)

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0.

To complete this protocol you will need:

1. Land use parcel layer (polygon)
2. Water layer (polygon) if water not included in land use parcel layer
3. Participant layer (point)
4. **Create Fishnet** tool (available from ESRI's ArcScripts website)
5. **XTools** extension (available from the Downloads section of the ESRI website)
6. **Excel**

The basic steps are:

- *Create Grids*
- *Create Unique ID Numbers for Grid Cells*
- *Calculate Majority Land Use for each Grid Cell*
- *Calculate Dissimilarity Indices in Excel*
- *Join Dissimilarity Data to Cells of Interest (Participants)*

Create Grids

11. Ensure that the data view is using the desired units for measurement by checking the lower right corner of the status bar at the bottom of ArcMap.
12. Move the mouse to the left-most extent of the area for which grid cells will be created. Zoom in and note the X coordinate.
13. Move the mouse to the bottom-most extent of the area for which grid cells will be created. Zoom in and note the Y coordinate.
14. Measure the approximate horizontal and vertical distances that need to be covered by the grid and divide each distance by the intended size of each grid cell. This will yield the number of rows and columns needed in the grid.
15. Click the Create Fishnet button that was added to the toolbar during the installation of the tool.
16. Enter the X-Y coordinates recorded above (this will identify the lower left corner of the area).
17. Enter the number of rows and columns estimated above.
18. Enter the height and width of each grid cell (100*100 meters for our purposes).
19. Choose a location and name for the output shapefile
20. Click the Edit button to select the coordinate system of the output shapefile.

21. Make sure it is set to product Polygons and click OK.

Create Unique ID Numbers for Grid Cells

1. Open the attribute table for the 100*100 meter grid cells.
2. Click on 'Options' and then 'Add Field...'.- 3. Name the field and click on 'OK'.- 4. Right click on the field name and select 'Calculate values...'.- 5. In the formula box, set the new field to be equal to the FID.- 6. Click 'OK'. Each cell will now have a unique ID, numbered consecutively from bottom to top beginning with the left-most column.

Calculate Majority Land Use for each Grid Cell

1. Open the ArcToolbox.
2. Click on Conversion Tools, To Raster, Feature to Raster.
3. For 'Input features' select your land use layer.
4. For 'Field' select the field containing your land use codes.
5. Name your output file.
6. For 'Output cell size' enter 10 (meters).
7. Click on 'OK'. A raster with 10*10 meter grid cells containing land use data will have been created (the first cell will be located in the lower left corner of the data layer's extent).
8. In the ArcToolbox, click on Spatial Analyst Tools, Zonal, Zonal Statistics.
9. For 'Input raster or feature zone data' select your 100*100 meter grid cell file.
10. For 'Zone field' select your unique ID field.
11. For 'Input value raster' select your 10*10 meter land use raster file.
12. Name your output file.
13. Under 'Statistics type' select 'MAJORITY'.
14. Check the 'Ignore NoData' option.
15. Click on 'OK'. The majority land use in each 100*100 meter grid cell (calculated based on the 100 10*10 meter grid cells contained within) will be assigned in the new 100*100 meter grid cell layer (raster).
16. In the ArcToolbox, click on Conversion Tools, From Raster, Raster to Polygon.
17. For 'Input raster' select your 100*100 meter grid cell raster (just created).
18. For 'Field' select the field containing the land use codes.
19. Name your output file.
20. Deselect the 'Simplify polygons' option
21. Click 'OK'. The raster file will have been converted to a polygon file (although not yet divided back into 100*100 meter grid cells).
22. Using XTools, click on Feature Conversions, Shapes to Centroids.
23. For 'Input feature layer' select your ORIGINAL 100*100 meter grid cell layer.
24. Name your output file.
25. For 'Centroid location' select 'Center point'.
26. Click 'OK'. Your 100*100 meter grid cells will now have centroids.
27. Right click on your new centroid layer and select Joins and Relates, Join.
28. For 'What do you want to join to this layer?' select 'Join data from another layer based on spatial location'.
29. For #1, select your new 100*100 meter grid cell layer (now with land uses).
30. For #2, select the first option 'Each point will be given all the attributes of the polygon that . . . it falls inside.'
31. For #3, name your output file.
32. Click 'OK'. The centroids of the 100*100 meter grid cells will now contain the land use data.
33. Right click on your ORIGINAL 100*100 meter grid cell layer and select Joins and Relates, Join.
34. For 'What do you want to join to this layer?' select 'Join data from another layer based on spatial location'.
35. For #1, select your centroid layer (now with land uses).
36. For #2, select the second option 'Each polygon will be given all of the attributes of the point that is closest to its boundary . . .'

37. For #3, name your output file.
38. Click 'OK'. You now have a 100*100 meter grid cell layer that contains data on the dominant underlying land use.

Calculate Dissimilarity Indices in Excel

1. Using XTools, click on Table Operations, Export Data to MS Excel.
2. For 'Feature layer' select your new 100*100 meter grid cell layer with land uses.
3. For 'Select fields to export' select the Unique ID number and the land use code.
4. Click 'OK'.
5. In Excel, create a new column to contain the dissimilarity indices.
6. For each cell (Unique ID number), build a formula that calculates the dissimilarity index for that cell (see Comments and Explanations above for a detailed description of our Excel formula).
7. For cells that contain no data (especially along the edges of irregular study areas), you may wish to assign an easily identifiable code in the dissimilarity index column (we used 999). This will make it easy to later identify and remove (or not display) these cells.
8. When finished, save the worksheet in DBF 4 (dBase IV) format.

Join Dissimilarity Data to Cells of Interest (Participants)

1. Right click on your new 100*100 meter grid cell layer and select Joins and Relates, Join.
2. For 'What do you want to join to this layer?' select 'Join attributes from a table'.
3. For #1, select your Unique ID number field.
4. For #2, select your dbf file that contains the dissimilarity numbers.
5. For #3, select your Unique ID number field.
6. Click 'OK'. The dissimilarity number will now be joined to your 100*100 meter grid cell layer.
7. Right click on your grid cell layer and select Open Attribute Table.
8. Under 'Options', select Add Field...
9. Name your field. Under 'Type' select Double. For Precision and Scale use numbers that fit your data (we used 8 for Precision and 3 for Scale).
10. Click 'OK'.
11. Right click on the name of your new field and select 'Calculate Values...'
12. Set your new field equal to the dissimilarity index field and click on 'OK'.
13. Right click on your new 100*100 meter grid cell layer and select Joins and Relates, Remove Join(s), Remove All Joins.
14. Your 100*100 meter grid cell layer will now contain dissimilarity data for each grid cell. If desired, you can pull out the data for specific cells of interest (such as those that contain the location of individual study participants) by performing a 'Join' of the grid cell data to the participant points file (note that some grid cells may be repeated since there may be more than one participant in a given grid cell).

5.7 Proportion of Dissimilar Land Uses Among Grid Cells in an Area, Formula 1

1. Basic Concept

The basic idea here is to use the dissimilarity calculation in the previous protocol to come up with an average dissimilarity over a larger area. Cervero and Kockleman (1996) examined a census tract scale but a number of different geographies could be used including ones of more uniform size than tracts. For example the index could be calculated for whole neighborhoods or for cells inside or intersecting with a small buffer distance around an individual.

2. Basic Formula

Following Cervero and Kockelman (1996, 8) the formula is: Proportion of Dissimilar Land Uses Among Grid Cells in an Area = $\frac{(\sum_j^k \sum_1^8 (X/8))}{K}$, where K is the number of developed grid cells

in the tract and “ $X_1 = 1$ if land use category of neighboring Hectare grid-cell differs from hectare grid cell j (0 otherwise).”

3. Detailed Formula

Following Cervero and Kockelman (1996, 8) the formula is: Proportion of Dissimilar Land Uses Among Grid Cells in an Area = $\{\sum_j^k \sum_i^8 (X/8)\} / K$, where K is the number of developed grid cells in the study geography such as a buffer, and “ $X_1 = 1$ if land use category of neighboring Hectare grid-cell differs from hectare grid cell j (0 otherwise).”

4. Comments and Explanations

We considered changing the formula to a median dissimilarity, but decided to use the average of grid cell indices instead of the median because the spread is low and we are trying to pick up differences (median will hide differences).

In order to be consistent with other measures in this manual, we decided to use only the grid cells that had their centroids within each buffer. This required an intermediate step in our process that selects only those cells whose original (not intersected) centroid falls within the buffer boundary.

Very large layers of grid cells intersected with buffers may have to be split into smaller pieces before they can be dissolved (then merged back together). The intersection of grid cells with our largest buffer (1600m) resulted in 4.1 million records!

5. GIS Approach

The basic steps to calculate the average dissimilarity index across an area are:

1. Begin by creating cell by cell dissimilarity as outlined above.
2. Intersect the grid cells with buffers.
3. Dissolve the layer based on buffer ID and unique grid cell ID.
4. Select only the cells that contain centroids from the original grid cells. Export as a new data layer.
5. Join to original grid cell layer (via unique ID) and copy over the dissimilarity indices.
6. Use the Summarize function to average the indices for each buffer.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0.

To complete this protocol you will need:

1. Cell by cell dissimilarity layer (polygon)
2. Grid cell centroid layer (point)
3. Buffer layer (polygon)

The basic steps are:

- *Generate Cell by Cell Dissimilarity Indices*
- *Roll Up Grid Cell into Areas*
- *Assign Dissimilarity Indices*
- *Calculate Average Dissimilarity Indices*

Generate Cell by Cell Dissimilarity Indices

1. Follow steps outlined above in Protocol 5.6

Roll Up Grid Cells into Areas

1. From ArcToolbox, select Analysis Tools, Overlay, Intersect

2. For 'Input Layers' select your grid cell layer and your buffer layer
3. Name your output layer
4. Click 'OK'
5. Once your intersected layer has been completed, from ArcToolbox select Data Management Tools, Generalization, Dissolve
6. For 'Input Layer' select your intersected layer (grid cells and buffer)
7. Name your output layer
8. For 'Dissolve Fields' select your buffer ID and the unique ID of the grid cells
9. Click 'OK'

Assign Dissimilarity Indices

1. Under 'Selection' choose 'Select by Location'
 - a. For 'I want to:' choose 'select features from'
 - b. For 'the following layer(s):' choose your newly dissolved layer
 - c. For 'that:' choose 'contain'
 - d. For 'the features in this layer:' choose your grid cell centroid layer
 - e. Click 'Apply'
2. When this is complete, right click on the dissolved layer and select Data, Export Data
3. Choose 'Export: Selected features' and check 'Use the same Coordinate System as this layer's source data'
4. Name your output layer and click 'OK'
5. Right click on your new layer and select Joins and Relates, Join
6. Select 'Join attributes from a table'
 - a. For 'Choose the field in this layer that the join will be base on:' choose your unique ID
 - b. For 'Choose the table to join to this layer:' choose your original grid cell layer
 - c. For 'Choose the field in the table to base the join on:' choose your unique ID
 - d. Click 'OK'
7. Once the join is complete, right click on your layer and select Open Attribute Table
8. Under 'Options', select Add Field...
9. Name your field. Under 'Type' select Double. For Precision and Scale use numbers that fit your data (we used 8 for Precision and 3 for Scale)
10. Click 'OK'
11. Right click on the name of your new field and select 'Calculate Values...'
12. Set your new field equal to the dissimilarity index field and click on 'OK'
13. Once the values have been copied over, right click on your layer and select Joins and Relates, Joins, Remove all Joins
14. The layer will now contain the dissimilarity indices for all selected grid cells

Calculate Average Dissimilarity Indices

1. Right click on your layer and select Open Attribute Table
2. Right click on the dissimilarity index field and select 'Summarize'
3. Expand the options for your dissimilarity index field and check 'Average'
4. Click 'OK'
5. A new dbf file will be created that , for each buffer ID, contains the average of the dissimilarity indices of all the associated grid cells

5.8 Dissimilarity Index, Formula 2 (new in Version 2.1)

1. Basic Concept

This is a measurement based on work by Daniel Rodriguez and colleagues at the University of North Carolina (Song and Rodriguez 2005a). **Please contact us before using this measure as we are still checking it and making sure that we are using similar scales and other characteristics to the UNC team.** This second version of a Dissimilarity Index is familiar to those working in the area of racial segregation. As they outline:

Definition: The degree to which different land uses exist within the smaller unit of analysis (e.g., grids or neighbourhood) and this distribution pattern is typical throughout the larger unit of analysis (e.g., neighbourhood or the city). The value of the index ranges between 0 and 1. A value of 0 means perfect similarity; a value of 1 means perfect dissimilarity. This measure is borrowed from Duncan and Duncan (1955) who employed it to reflect the level of residential segregation and has received strong endorsement from recent findings that it is effective to capture the evenness dimension of residential segregation (Massey and Denton, 1988). The measure is implemented in the Appendix for two land uses (e.g., residential and non-residential land uses) and for various land use types simultaneously.

Unit of analysis: Different levels of neighbourhoods (e.g., grids, census boundaries, or metropolitan areas). (Song and Rodriguez 2005a, 9)

The UNC team's web site is

<http://planningandactivity.unc.edu/Activities%20and%20News.htm>

2. Basic Formula

The UNC team chose to use a formula focused on two basic land use types, residential and non-residential. As they explain:

“Measurement 1: The following formula can be used to measure the evenness between residential use and non-residential land uses.

$$D = 0.5 \sum_{i=1}^n |X_i - Y_i|$$

The first implementation of the index, D_N , is to examine if the distribution of land uses at sub-neighbourhood level (i.e., a grid cell) is similar to the distribution pattern at the neighbourhood level. We denote n as the number of grids in the neighbourhood, X_i as the ratio of the residential area in grid i to the residential area in the neighbourhood, and Y_i as the ratio of the non-residential area in grid i to the non-residential area in the neighbourhood” (Song and Rodriguez 2005a, appendix 4).

In their format the index is measured for grid cells (we chose 100m) and then compared with the larger study geography. In their case this is a neighbourhood. **We are still determining what geography we will use for comparison.**

“Then the comparison of the distribution of land uses within each of the grids to the neighbourhood as a whole can be made. The index of dissimilarity equals to 0 if distribution of land uses within each grid is similar to the distribution at the neighbourhood level, i.e., the proportions of the residential and non-residential land uses within each of the grids are identical to the proportions at the neighbourhood level respectively. The index equals to 1 if there are either only residential land uses, or there are only non-residential land uses within each of the grids” (Song and Rodriguez 2005a, appendix 4-5).

2. Basic Formula

$$D = 0.5 \sum_{i=1}^n |X_i - Y_i|$$

In other words, Dissimilarity =
the ratio of the residential area in grid cell number 1 to the ratio in the larger comparison measurement geography (the “neighbourhood”) minus the ratio of the non-residential area in grid cell number 1 to the non-residential area in the neighbourhood
+ the same calculation for grid cells 2, 3, 4 etc., all divided by 2.

3. Detailed Formula

This formula uses the simplified land uses from earlier protocols.

4. Comments and Explanations

We are still coordinating the exact operation of this measurement with the University of North Carolina team. The key issue is defining the “neighborhood” or higher level measurement geography.

5. GIS Approach

This is taken directly from draft work by Song and Rodriguez and should be cited as being by them. The citation is Song, Yan and Daniel A. Rodríguez. 2005b. Steps for Computing the Dissimilarity, Entropy, Herfindahl-Hirschman and Accessibility (Gravity with Competition) Indices. Draft Manuscript. Please, however, check their web site for updated versions of these steps: <http://planningandactivity.unc.edu/Activities%20and%20News.htm>

1. “Decide to which neighbourhood each taxlot belongs:
 - a. Convert the taxlot polygons into centroids by using XTool;
 - b. Spatial join the neighbourhood polygons and the taxlot centroids so that each taxlot would be assigned with a neighbourhood ID and all taxlot centroids that are inside a neighbourhood will have the same neighbourhood ID;
2. Construct grids which would intersect with the study area:
 - a. create grids with user-defined size by using “Coordinate Grid Maker 2.290” ArcView script which can be downloaded from ESRI’s website;
3. Assign each taxlot by grid:
 - a. Spatial join the grid (polygon) shape file and the taxlot centroids (point) shape file so that all taxlot centroids that are inside a grid cell will have the same grid cell ID;
4. Calculate total area of residential uses for each grid cell by summarizing the table of taxlot centroids shape file based on the grid cell ID. You would obtain a table with the grid cell ID as the key. Each grid cell also has a neighbourhood ID indicating the neighbourhood to which the grid cell belongs.
5. Calculate total area of non-residential uses for each grid cell by summarizing the table of taxlot centroids shape file based on the grid cell ID. You would obtain a table with the grid cell ID as the key. Each grid cell also has a neighbourhood ID indicating the neighbourhood to which the grid cell belongs.
6. Based on the common grid cell ID, combine the table created from step 4 and the table created from step 5 into a single table. The resulted new table includes the following fields: grid cell ID (key), residential area by each grid cell, non-residential area by each grid cell, and neighbourhood ID.
7. Using the attribute table of taxlot centroids, calculate total residential area by each neighbourhood by summarizing residential area based on neighbourhood ID. This would result a table with neighbourhood ID as the key.

8. Using the attribute table of taxlot centroids, calculate total non-residential area by each neighbourhood by summarizing non-residential area based on neighbourhood ID. This would result a table with neighbourhood ID as the key.
9. Based on the common grid cell ID, combine the table created from step 7 and the table created from step 8 into a single table. The resulted new table contains the following fields: neighbourhood ID (key), residential area by each neighbourhood, and non-residential area by each neighbourhood.
10. Based on the common neighbourhood ID, join the table created from step 9 to the table created from step 6. In addition to the existing fields in the table created from step 6, the new table will also have information on total area of neighbourhood residential and non-residential uses by each grid cell.
11. In the table created from step 10, divide total residential area in grid cell by total residential area in neighbourhood. A new field containing the information on the ratio is added to the table.
12. In the table created from step 11, divide total non-residential area in grid cell by total non-residential area in neighbourhood. A new field containing the information on the ratio is added to the table.
13. Calculate the difference between the two ratios obtained from step 11 and 12 and add the new field - ratio difference - to the table.
14. Calculate Dissimilarity Index:
 - a. Use the table created from step 13 to summarize the grid cell ratio differences by neighbourhood ID;
 - b. Divide the summarized total differences by 2 for each neighbourhood. This is the value of dissimilarity index for each neighbourhood.”(Song and Rodriguez 2005b)

6. GIS Steps
[To add]

5.9 Entropy Index (new in Version 2.1)

1. Basic Concept

This is a measurement based on work by Daniel Rodriguez and colleagues at the University of North Carolina (Song and Rodriguez 2005). *Please contact us before using this measure as we are still checking it and making sure that we are using similar scales and other characteristics to the UNC team.* As they outline:

Definition: The entropy index is a measure of variation, dispersion or diversity (Turner *et al.*, 2001). It measures the degree to which land uses are heterogeneously distributed within a neighbourhood. A value of 0 indicates homogeneity, wherein all land uses are of one single type; a value of 1 means heterogeneity, wherein area is evenly distributed among all land use categories.

Unit of analysis: Neighbourhoods. (Song and Rodriguez 2005a, 10).

As they explain:

“The entropy index (Shannon Index) is commonly calculated through the following formula:

$$Entropy = \{-\sum_k [(p_i)(\ln p_i)]\}/(\ln k) \text{” (Song and Rodriguez 2005a, appendix 6)}$$

There are several ways to operationalize this and the UNC team has chosen the following:

Measurement: To examine the distribution pattern of different land uses within a neighbourhood, the index spells out that P_i = proportions of each of the six land use types such as single family residential, multi-family residential, commercial, industrial, public institutional and park uses, and k = the number of land uses. In this case, $k=6$ (Song and Knaap, 2004) (Song and Rodriguez 2005b).

The UNC team's web site is

<http://planningandactivity.unc.edu/Activities%20and%20News.htm>

2. Basic Formula

Entropy = negative of proportion of land use (p) of type 1 times the log of that proportion, plus proportion of land use (p) of type 2 times the log of that proportion, and so on for each of " k " land use categories all divided by the log of " k ."

3. Detailed Formula

If the proportion of a land use type in a given neighborhood is 0, taking the log of that land use would result in an undefined term, preventing the completing of the calculation. To work around this problem, Rodriguez suggests the following fix:

For each land use i , the term is $P_i \cdot \ln(P_i)$. To calculate, we take the following shortcut: If P_i is zero, then the whole term would be zero, even if $\ln(P_i)$ is undefined (in other words, that land use does not contribute to the entropy -- the key is to view entropy as the sum of proportions of each land use, weighed by the natural log of those proportions) (from personal e-mail correspondence, Rodriguez 2005).

4. Comments and Explanations

The University of North Carolina team defined "neighborhoods" as buffers of $\frac{1}{8}$, $\frac{1}{4}$, and $\frac{1}{2}$ mile around an individual's home. To be consistent with our other measures, we used similarly-sized buffers of 200m, 400m, and 800m (both straight-line and network).

Some of our 200m network buffers had no land use area associated with them (see explanation in Section 2.6). For these buffers, we recorded "No Data", rather than using values of 0, to distinguish them from buffers with calculated indices of 0 (which indicate perfect homogeneity).

5. GIS Approach

This is taken directly from draft work by Song and Rodriguez and should be cited as being by them. The citation is Song, Yan and Daniel A. Rodríguez. 2005b. Steps for Computing the Dissimilarity, Entropy, Herfindahl-Hirschman and Accessibility (Gravity with Competition) Indices. Draft Manuscript. Please, however, check their web site for updated versions of these steps: <http://planningandactivity.unc.edu/Activities%20and%20News.htm>

1. "Decide to which neighbourhood each taxlot belongs:
 - a. Convert the taxlot polygons into centroids by using XTool;
 - b. Spatial join the neighbourhood polygons and the taxlot centroids so that each taxlot would be assigned with a neighbourhood ID and all taxlot centroids that are inside a neighbourhood will have the same neighbourhood ID;
2. Calculate the total area of each of the six land use types in each neighbourhood:

- a. Using the taxlot centroids attribute table, summarize the area of taxlots by each land use type and by neighbourhood ID. The resulted table includes the following fields: neighbourhood ID, land use type, and the total area by land use type.
3. Calculate total area of all land uses in each neighbourhood:
 - a. Using the taxlot centroids attribute table, summarize the area of taxlot by neighbourhood ID.
4. Based on the common neighbourhood ID, join the table created from step 3 to the table created from step 2. The new table includes the following fields: Neighbourhood ID, land use type, area by land use type, and total neighbourhood area.
5. Using the table created from step 4, divide the area of each single land use type by total neighbourhood area. New fields – proportions of each land use type (P_i) – are added to the table.
6. Calculate $(p_i)(\ln p_i)$ and create the new fields with the values.
7. Calculate $\{\sum_k [(p_i)(\ln p_i)]\}$: Summarize the field $(p_i)(\ln p_i)$ for all 6 land use types by neighbourhood ID and create new fields.
8. Finally calculate entropy index for each neighbourhood using the formula: $Entropy = \{-\sum_k [(p_i)(\ln p_i)] / (\ln k)\}$. (Song and Rodriguex 2005b)

6. GIS Steps

No additional GIS Steps were taken for this measurement. All calculations were done in Excel based on previous GIS work for Percentage of Total Land Area in Major Uses (Section 5.1).

5.10 Herfindahl-Hirschman Index, HHI (new in Version 2.1)

1. Basic Concept

This is a measurement based on work by Daniel Rodriguez and colleagues at the University of North Carolina (Song and Rodriguez 2005). *Please contact us before using this measure as we are still checking it and making sure that we are using similar scales and other characteristics to the UNC team.*

As they outline:

“Definition: The Herfindahl-Hirschman Index (HHI index), a commonly accepted measure of market concentration used to detect market monopoly, can be used to assess the level of land use mixture. The HHI index is the sum of squares of the percentages of each type of land uses in the user-defined neighbourhoods. If there is only one land use type in the neighbourhood, HHI index will equal 10,000. The higher the value of HHI Index, the lower the level of land use mixture.

Unit of analysis: Neighbourhoods. (Song and Rodriguez 2005, 9)”

As Song and Rodriguez (2005b) elaborate: “Following the same notation as the entropy index, the formula of calculating HHI among k uses of land is:

$$HHI(k) = \sum_{i=1}^K (P_i * 100)^2$$

where P_i is the percentage of each type of land use in the neighbourhood, and K is the number of land use types.”

The UNC team’s web site is

<http://planningandactivity.unc.edu/Activities%20and%20News.htm>

2. Basic Formula

The Herfindahl-Hirschman Index = the percentage of land use type 1 times 100 and then squared, plus the percentage of land use type 2 times 100 and then squared (and so on for the seven major types (residential, commercial, office, industrial, institutional, park and recreation, vacant)).

3. Detailed Formula

As above.

4. Comments and Explanations

Similar to the calculations of the Entropy Index, we used buffers (neighborhoods) of 200m, 400m, and 800m around each individual.

In addition, we based our area calculations on the range of seven major land uses defined in section 5.1.

5. GIS Approach

This is taken directly from draft work by Song and Rodriguez and should be cited as being by them. The citation is Song, Yan and Daniel A. Rodríguez. 2005b. Steps for Computing the Dissimilarity, Entropy, Herfindahl-Hirschman and Accessibility (Gravity with Competition) Indices. Draft Manuscript. Please, however, check their web site for updated versions of these steps: <http://planningandactivity.unc.edu/Activities%20and%20News.htm>

1. "Using the table created from step 4 in the entropy index, divide the area of each single land use type by total neighbourhood area. New fields – proportions of each land use type (P_i) – are added to the table.
2. For each newly created field in step 1, calculate $(p_i \cdot 100)^2$ and create i new fields with these new values.
3. Calculate $\sum_k (P_i \cdot 100)^2$: Summarize the field created in step 2, $(p_i \cdot 100)^2$, for all k land use types by neighbourhood ID and create new fields" (Song and Rodriguez 2005b).

6. GIS Steps

No additional GIS Steps were taken for this measurement. All calculations were done in Excel based on previous GIS work for Percentage of Total Land Area in Major Uses (Section 5.1).

Employment Per Unit Land Area (see 3.6 in density section)

5.11 Retail Employment per Unit Area

1. Basic Concept

Retail uses are thought to promote walking.

2. Basic Formula

Retail Employment per Unit Area = Total retail employees per unit land area (excluding water).

3. Detailed Formula

Retail Employment per Unit Area = Total retail (SIC codes 5200-5999) employees per unit land area (excluding water).

4. Comments and Explanations

We used SIC codes to correspond with earlier research. In later versions of these protocols we will provide the NAICS equivalent.

Retail data came from Dun and Bradstreet but were checked against other employment data.

In an earlier version of the protocols we proposed that the measure be made in increments of 100*100 meter grid cells. However, we gained access to point data and could then use standard buffers.

5. GIS Approach

Divide the retail employment in each grid cell by that cell's area (excluding water). To determine retail employment density for an entire focus or context area, summarize the attributes of the grid cells by focus or context area ID and include the sum of the total employment field and the sum of the grid cell hectares field.

The process is similar for other geographies such as buffers, though a decision needs to be made whether grid cells that are cut by a measurement geography have their value included, excluded, or apportioned.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Study site layer (polygon) with unique ID field
2. Participant locations layer (point)
3. Employment data (point)
4. Water features layer (polygon)
5. **XTools** extension (available from the Downloads section of the ESRI website)

Create participant buffers:

1. Add the participant locations layer to your Map Document
2. Under the Tools dropdown menu, select "Buffer wizard"
3. In the Buffer Wizard window, under "The features of a layer" select your participant locations layer and click on *Next*
4. Click "At a specified distance" and enter XX (your desired distance)
5. After "Distance units are:" select *meters*
6. Click *Next*
7. After "Dissolve barriers between" select *No*
8. Give the layer a name and save as a new layer
9. Click *Finish*

Query the employment data to show only retail businesses:

1. Add the employment layer to your Map Document.
2. Right click on the employment layer in the Table of Contents and choose Properties
3. Click the Definition Query tab
4. Click on the Query Builder button
5. Construct a query that will identify all retail employment businesses (in our case, "SIC_RET" = 1)
6. Click OK to close the Query Builder and OK again
7. The employment layer should be updated to show only retail businesses in the data view

Perform a spatial join between the participant buffers and employment layer

1. Right click the buffer layer and choose Joins and Relates→Join
2. In the top drop down box, make sure it is set to Join data from another layer based on spatial location
3. In the next item down, select the employment layer to be the layer to join to the buffers
4. Click to button to select Each polygon will be given a summary of the numeric attributes... and check the box below next to Sum
5. At the bottom, choose a name and location for the output file
6. Click on OK

The resulting file will have a field in its Attribute Table called Sum_EMPL or similar (depending on the name of the field containing the number of employees in the original employment layer). The new layer should have the same number of features as the buffer layer.

Refer to the protocol 2.1 for calculating Net Land Area (excluding water). Create a study site polygon layer that has had water features erased from it and area data updated. Join the attribute table of the layer created in the spatial join above to the Attribute Table of the study site layer with water removed based on the ID field.

1. Add a new field to the Attribute Table of type double called RetPerHect or similar.
2. Right click on this field and choose Calculate Values
3. In the Field Calculator, double click the field containing the sum of retail employees, click the / button, and then double click the Hectares field from the study site table
4. Hit OK

The RetPerHect field now contains the number of employees per hectare (excluding the area of water features).

5.12 Density of Employees in Major Retail Subcategories (Separate Measures): General Merchandise (old SIC 53xx); Food Stores (54xx); Eating and Drinking Places (58xx); Miscellaneous Retail (59xx).

1. Basic Concept

While retail in general is thought to be an important predictor of walking, there is considerable interest as to whether a smaller subset of retail is the most important (Krzek 2003a, 2003b). This protocol enables these retail subcategories to be measured individually and as a combination, rather as the major land uses protocol above did.

2. Basic Formula

Density of Employees in Major Retail Subcategories = Total retail employees in each of the four categories above (or all four together) per unit land area (excluding water).

3. Detailed Formula

Density of Employees in Major Retail Subcategories = Total retail employees in each of the four categories above (or all four together) per unit land area (excluding water).

4. Comments and Explanations

We used SIC codes to correspond with earlier research. In later versions of these protocols we will provide the NAICS equivalent.

These data will come from both state employment figures and Dunn and Bradstreet—however, so far we have only received the Dunn and Bradstreet data. Data are for businesses in that SIC code with fewer than 200 employees (following Krizek 2003a, 2003b).

In an earlier version of the protocols we proposed that the measure be made in increments of 100*100 meter grid cells. However, we gained access to point data and could then use standard buffers.

5. GIS Approach

Divide the general merchandise employment in each grid cell by that cell's area (excluding water). To determine general merchandise employment density for an entire focus or context area, summarize the attributes of the grid cells by focus or context area ID and include the sum of the general merchandise employment field and the sum of the grid cell hectares field.

The process is similar for other geographies such as buffers, though a decision needs to be made whether grid cells that are cut by a measurement geography have their value included, excluded, or apportioned.

Repeat for food stores, eating and drinking places, and miscellaneous retail.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0.

To complete this protocol you will need:

Participant buffer layer (polygon)

Employment data (point)

Water features layer (polygon)

XTools extension (available from the Downloads section of the ESRI website)

Start a new ArcMap document and add the employment layer and buffer layer to the view (see Protocols 2.5 or 2.6 for steps to create buffers)

Query the employment data to show only general merchandise businesses:

1. Add the employment layer to your Map Document.
2. Right click on the employment layer in the Table of Contents and choose Properties
3. Click the Definition Query tab
4. Click on the Query Builder button
5. Build a query that will identify all general merchandise businesses (in our case, "SIC_GM" = 1)
6. Click OK to close the Query Builder and OK again
7. The employment layer should be updated to show only general merchandise businesses in the data view

Perform a spatial join between the participant buffers and employment layer

1. Right click the buffer layer and choose Joins and Relates→Join
2. In the top drop down box, make sure it is set to Join data from another layer based on spatial location
3. In the next item down, select the employment layer to be the layer to join to the buffers
4. Click to button to select Each polygon will be given a summary of the numeric attributes... and check the box below next to Sum
5. At the bottom, choose a name and location for the output file
6. Click on OK

The resulting file will have a field in its Attribute Table called Sum_Empl or similar (depending on the name of the field containing the number of general merchandise employees in the original employment layer). The new layer should have the same number of features as the buffer layer.

Refer to the protocol 2.1 for calculating Net Land Area (excluding water). Create a study site polygon layer that has had water features erased from it and area data updated. Join the attribute table of the layer created in the spatial join above to the Attribute Table of the study site layer with water removed based on the ID field.

1. Add a new field to the Attribute Table of type double called GMPerHect or similar.
2. Right click on this field and choose Calculate Values
3. In the Field Calculator, double click the field containing the sum of general merchandise employees, click the / button, and then double click the Hectares field from the study site table
4. Hit OK

The GMPerHect field now contains the number of general merchandise employees per hectare (excluding the area of water features).

5.13 Distance to Nearest Facility with Employees in Major Retail Subcategories (Separate Measures): General Merchandise (old SIC 53xx); Food Stores (54xx); Eating and Drinking Places (58xx); Miscellaneous Retail (59xx).

1. Basic Concept

More important than the density of retail may be the distance to the nearest retail establishment.

2. Basic Formula

Distance to Nearest Facility = Straight line or network distance to the centroid of the nearest facility of a certain type.

3. Detailed Formula

Same as above.

4. Comments and Explanations

The straight line distance part of this measurement uses an ArcView extension called Nearest Features. It can be downloaded here:

http://www.jennessent.com/arcview/nearest_features.htm

The network distance to nearest part of this measurement uses an ArcView extension called Multiple Closest Facilities. It can be downloaded from the ESRI website at

<http://arcscripits.esri.com/details.asp?dbid=13125>

5. GIS Approach

The GIS approach involves determining the straight line and network distance between an origin (in this case participant locations) and the closest of the possible destinations (in this case, locations of various subcategories of retail).

6. GIS Steps

I. Straight line distance to nearest facility

The following procedures were completed using ArcView 3.3.

To complete this protocol you will need:

5. Roads layer (polyline)
6. A set of origin features—in this example, participant locations (point)
7. A set of retail subcategory locations (point)
8. The Nearest Features extension for ArcView

Prepare the view and data:

7. Add the roads theme and the participant locations / retail location themes to a new view
8. Go to the *View* menu and choose *Properties*
9. Set the map units and distance units appropriate for the coordinate system of the layers
10. Go to the *File* menu and choose *Extensions*
11. Find the Nearest Features extension and check the box to turn it on
12. Click *OK*

Calculate distance to nearest feature

11. Click on the Nearest Features button in the toolbar
12. In the first dialog box, select the theme of participant locations and the field in its table that contains a unique ID
13. Click *OK*
14. In the next dialog box, select one or more destination themes (if you want to calculate the distance to nearest feature for more than one kind of feature at a time), and for each theme choose a field containing a unique ID
15. Click *Add* for each combination of feature and unique ID
16. Click *OK* when finished
17. In the next dialog box, enter the number of nearest features you want to find (1 = nearest feature, 2 = nearest and second-nearest features, etc) and check the boxes for Comparison Feature ID and Distance to Centroid
18. Click *OK*
19. In the final dialog box, you may choose to draw lines connecting each participant location and its nearest retail location (this will increase processing time)
20. Click *OK* to begin the processing

The output will be a table containing the unique ID of each participant location, the unique ID of the nearest retail location, and the distance between them in the chosen units of the view.

II. Network distance to nearest facility

The following procedures were completed using ArcView 3.3.

To complete this protocol you will need:

11. Roads layer (polyline)
12. A set of origin features—in this example, participant locations (point)
13. A set of destination features—in this example, retail subcategory employment locations (point)
14. The Network Analyst extension for ArcView
15. The Multiple Closest Facilities extension for ArcView

Calculate network distance to nearest facility

27. Start a new ArcView project and create a blank View
 - a. Open the *View* menu and choose *Add Theme*
 - b. Add the roads, origins, and destinations layers to the View
 - c. Open the *View* menu and choose *Properties*
 - d. Make sure the map units (meters, feet, etc.) match the units of the data layers
 - e. Open the *File* menu and choose *Extensions*

- f. Check the box next to the *Multiple Closest Facilities* extension and click *OK*
28. Open the *Network Tools* menu that has been added and choose *Multiple closest facilities*
29. In the dialog box that appears, select the participant locations layer in the *From* dropdown box
30. Select the unique ID of the participant locations layer in the *From ID field* dropdown box
31. In the *To* dropdown box, select the retail locations layer
32. Choose the unique ID of the retail locations layer in the *To ID field* dropdown box
33. In the *Network* dropdown box, select the roads layer
34. For *Facilities to find*, enter 1
35. Set the *Cutoff Distance* to 0
36. The *Search Tolerance* is a distance in the current map units that Network Analyst will search away from the road features to find points. Make this number large enough so the process will not miss any of the participant locations
37. Click *Travel to facility*
38. Check the box for *Create Join Table*
39. Hit *Process*

When the process ends, the extension will add a new polyline feature to the View consisting of the network segments that trace the shortest path from each participant location to its nearest retail location. The table of the new layer contains an Origin field with the unique ID of the participant location layer, a Destin field with the unique ID of the closest retail location, and a Length field with the distance in the current map units between the participant location and the closest retail location.

5.14 Distance to Nearest Facility for Comparison with NQLS Survey

1. Basic Concept

This set of measures has two purposes. It starts with a set of facilities that have been identified in the Neighborhood Quality of Life Survey (NQLS) developed by James Sallis and others. Using GIS we measure the physical distance between homes of subjects and these facilities. We can then assess (a) whether walking and physical activity is associated with measured distance to these facilities and (b) the correlations between the distances to the facilities measured using GIS and the survey responses (perceived distances).

2. Basic Formula

Distance to Nearest Facility = Straight line or network distance to the centroid of the nearest facility of a certain type.

3. Detailed Formula

Same as above.

4. Comments and Explanations

The NQLS survey includes a listing of “stores, facilities, and other things in your neighborhood.” Respondents can say I they are within the following walking distances: 1-5 minutes, 6-10, 11-20, 20-30, or 30+. The following land uses are asked about in the NQLS survey but only those highlighted in bold were available in land use data at a detailed level in our area.

1. convenience/small grocery store
2. **supermarket**
3. hardware store
4. fruit/vegetable market
5. laundry/dry cleaners
6. clothing store

7. post office
8. library
9. elementary school
10. other schools
11. book store
12. fast food restaurant
13. coffee place
- 14. bank/credit union**
15. non-fast food restaurant
16. video store
17. pharmacy / drug store
18. salon / barber shop
- 19. your job (available from survey)**
- 20. bus or trolley stop**
- 21. park**
22. recreation center
23. gym or fitness facility

To do this one has to convert walking times to distances. We used 3 miles per hour as the comparison and took the outer limit of the time (i.e. 5 minutes, 10, 20, 30, and further).

5. GIS Approach
[To add.]

6. GIS Steps
[To Add]

5.15 Gravity Measure with Competition (new in Version 2.1)

1. Basic Concept

This is a measurement based on work by Daniel Rodriguez and colleagues at the University of North Carolina (Song and Rodriguez 2005). *Please contact us before using this measure as we are still checking it and making sure that we are using similar scales and other characteristics to the UNC team.*

As they describe:

Definition: The simplest gravity-based measure of land use mix can be defined as the sum of accessibility of residential land use to all other given type of non-residential land uses, discounted by the distance decay function between these two points.

Unit of analysis: Individual land parcels or neighbourhoods. (Song and Rodriguez 2005, 6).

Mathematically, Song and Rodriguez (2005b) outline the following:

$$AG_i = \frac{\sum_{j=1}^n A_j d_{ij}^{-\beta}}{\sum_{k=1}^m d_{kj}^{-\beta}}$$

“where

AG_i = accessibility of residential land use (e.g., house units or neighbourhoods) i to non-residential land use (e.g., non-residential land parcels or activity centres) j

A_j = attractiveness of non-residential land use j , in this case, it's measured by floorspace of retailing stores
 d_{ij} or d_{kj} = distance from residential use i , or housing unit k , to non-residential use j
 $d_{ij}^{-\beta}$ or $d_{kj}^{-\beta}$ = impedance function based on the inverse power function
 β = distance decay parameter
 n = number of one type of non-residential land uses
 m = number of residential land uses."

The UNC team's web site is

<http://planningandactivity.unc.edu/Activities%20and%20News.htm>

2. Basic Formula

See above.

3. Detailed Formula

See above.

4. Comments and Explanations

We are still coordinating the exact operation of this measurement with the University of North Carolina team. The specific geography still needs to be defined and some of the variables need to be more clearly defined.

5. GIS Approach

This is taken directly from draft work by Song and Rodriguez and should be cited as being by them. The citation is Song, Yan and Daniel A. Rodríguez. 2005b. Steps for Computing the Dissimilarity, Entropy, Herfindahl-Hirschman and Accessibility (Gravity with Competition) Indices. Draft Manuscript. Please, however, check their web site for updated versions of these steps: <http://planningandactivity.unc.edu/Activities%20and%20News.htm>

1. "Import the attribute table of single family taxlots to Microsoft Access database named as "db1.mdb" and name the table as "SFR".
2. Import the attribute table of commercial stores to "db1.mdb" database and name the table as "STORE".
3. Create a new table named as "RES" to store the information on distances and store floorspaces. Modify the table by applying the developed C++ program.
4. Create a new table named as "NEWSTORE" to store the information on the summation of distances among single family housing units to commercial stores. Apply the developed C++ program to obtain the values.
5. Create a new table named as "ACCESS" to store the final values of the index. Apply the developed C++ program to obtain the final values.

Note: You need *Microsoft Visual C++* along with *ADO* to run the developed C++ program. The code snippet is available upon request. "

6. GIS Steps

[To Add]

6. STREET PATTERN

Chapter by: Ann Forsyth (drafting, conceptual issues and formulae, some comment text) and Jason Zimmerman (all the terrific illustrations, most comments, GIS Steps and the GIS approach text); comment text represents discussions between Ann Forsyth, Joel Koepp, and Jason Zimmerman.

Compared with Version 2.0 of these protocols there are few changes, except for moving the Link-Node ratio to the end and to add an explanation to 6.2. There were basically no changes between versions 2.1 and 2.2.

Background

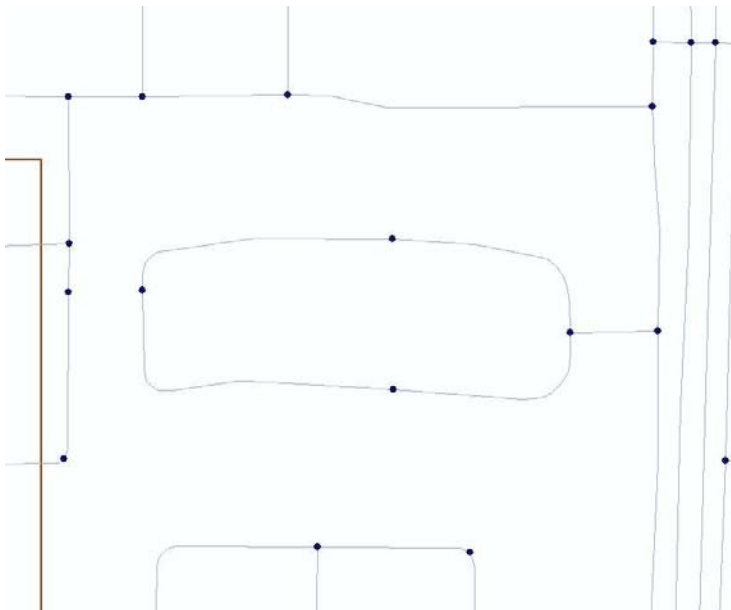
Streets and paths are the routes that people generally use to move about the environment although this is not always the case as people can take short cuts and cuts-through in such environments as parks and parking lots.

In general, street pattern measures get at issues such as the number and directness of routes for pedestrians. Pedestrians appreciate the option of direct routes because they are exposed to the weather and they appreciate options for reasons of variety and safety.

In the first round of Active Living Research grants Jennifer Dill (2003) was funded to examine the issue of measures of street pattern and we drew on her work in creating this chapter. Subsequent versions will also draw on more recent research by Steiner et al. (2004).

The next version of this chapter will contain more detail about these conceptual issues, including more of a review of how earlier studies have dealt with the issue of street pattern.

One last issue is the construction of GIS databases. In some, every street segment is made of one or more lines (in ArcGIS called “arcs” that begin and end with “nodes”). In others, multiple segments are contained in one line. This has implications for how street intersections are counted.



The vast majority of our roads have nodes only at the beginning and end of the arc. This image shows both kinds—the nodes in the middle of the cul-de-sac segment get a valence of 2 and can be identified and ignored with a query when counting intersections.

6.1 Average Census Block Area

1. Basic Concept

The average census block area is an easy-to-calculate approximation for street pattern. Simply put, bigger blocks have fewer streets and/or more culs-de sac and unless they also have many additional pedestrian routes they will be harder to get around. As Dill (2003, 3) explains, block size is only an approximation as the shape of the blocks also affects the street pattern. This has been often used in previous research because it uses some form of census block which is easily available and average block size is easy to calculate in the ArcGIS programs (Hess et al 1999, 1-2,10; Krizek 2003 (APA), 269; Cervero and Duncan 2003, 1480).

However, in general we used median block size rather than average. This is because medians are, statistically, a preferred measure. As was explained in chapter one, this meant that we picked up a number of areas with mostly small blocks but one large land use (e.g. a golf course or large industrial area) that gave them a medium average block size but a low median.

[In a future version of these protocols we will discuss other related measures such as Ewing et al (2003, 50-51.)]

2. Basic Formula

Average Census Block Area = Average area for census blocks with a centroid falling within the measurement geography.

3. Detailed Formula

Same as above.

4. Comments and Explanations

The Centroid Rule

Because the whole block size is what matters, it is not possible to clip the blocks to the measurement geography. However, this leaves the question of which census blocks to include in the measure. We examined a number of options including:

- All census blocks that intersect the measurement geography
- All census blocks with a centroid within the measurement geography
- All census blocks completely contained within the measurement geography

The middle approach was selected because with this approach and a measurement geography that divided up an entire study area, for example into uniform grid cells, each block would fall within one and only one cell but also, every block would be counted as part of some cell.

Centroid Calculations—What Can Go Wrong

- When using version 8.3 of Arc GIS, We calculated centroids using XTools, which creates a separate point file. XTools uses a centroid calculation method that does not require the centroid to be within the boundaries of the shape. That is, in the coordinate system, it places the centroid at the average of the shape's minimum/maximum X and Y values. However, the Select by Location tool in ArcMap, from all the evidence, requires the "center" of a shape to be inside that shape's boundaries. In Arc 9 the toolbox for calculating centroids of polygons allows you to explicitly choose whether or not the centroid must be located within the bounds of the polygon, however the choice is still important in particular circumstances such as odd shaped census blocks (e.g. that bend around lakes). In this case results are different.

For consistency we used XTools, that is these protocols do not require the centroid to be within the polygon. For processes requiring selecting features based on whether or not their centroids are inside a focus/context area, that selection process needs to use an actual centroid point file in the Select by Location dialog, instead of using the polygons from which those centroids were derived and letting ArcMap use its different "have their centers in" method. [This will be explained more clearly in future versions of the manual.]

5. GIS Approach

Identify all census blocks with centroids in the measurement geography. Use a spatial join or an intersect to associate each census block with the ID of the measurement geography in which it is located. Summarize the attributes by the measurement geography ID, calculating the average of the Hectares field in the process.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

1. Site layer (polygon)
2. Census block layer (polygon)
3. **XTools** extension (available from the Downloads section of the ESRI website)

The basic steps are:

- *Create Centroid Layer*
- *Select Census Blocks*
- *Calculate Census Block Areas*
- *Calculate Average Census Block Areas for each Site*

Create Centroid Layer:

1. From the XTools drop-down menu, select "Feature Conversions" and choose "Shapes to Centroids".
2. Under "Select the layer you wish to convert:" select your census block layer.
3. Give the layer a name and click on "OK".
4. The new layer will be added to your map document.

Select Census Blocks:

1. Add the census block layer, the centroid layer, and the study site layer to your Map Document.
2. From the "Selection" drop-down menu, choose "Select by Location...".
3. Under "I want to:" choose "select features from".
4. Under "the following layers:" select your centroid layer.
5. Under "that" choose "have their center in".
6. Under "the features in this layer:" select your study site layer.
7. Hit "Apply". Now the centroids that fall inside your study sites will be selected.
8. From the "Selection" drop-down menu, choose "Select by Location...".
9. Under "I want to:" choose "select features from".
10. Under "the following layers:" select your census block layer.
11. Under "that" choose "contain".
12. Under "the features in this layer:" select your centroid layer.
13. Be sure the button for "Use selected features" is checked.
14. Hit "Apply". Now the census blocks that contain the selected centroids will be selected.
15. Right click on your census block layer and select "Data" and then "Export Data..."
16. After "Export:" choose selected features.
17. Choose "Use the same Coordinate System as this layer's source data."
18. Give the new layer a name and click on OK.

19. When prompted, add the new layer to the Map Document.

Calculate Census Block Areas:

1. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select your new census block layer
 - b. Under "Desired output units", choose your units (depending on the census block size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit "OK"
2. New fields called "Area" and "Hectares" will be created in the attribute table of your new census block layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

Calculate Average Census Block Areas for **multiple non-overlapping Sites**:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using a Spatial Join, assign the IDs from the sites to each census block in the new census block layer.
3. Open the attribute table of the new census block layer and select the field that contains the IDs.
4. Right-click on the field name and select Summarize.
5. Under "2. Choose one or more summary statistics..." expand the box labeled "Hectares" and check the box marked "Average".
6. Select or create an output file name and hit OK.
7. The output .dbf file will contain the average size, in hectares, of the census blocks from each study site.

Calculate Average Census Block Areas for **multiple overlapping Sites**:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using your site polygon layer, select (highlight) the first study site.
3. Perform a "Select By Location".
 - a. Under "I want to:" choose *select features from*
 - b. Under "the following layers:" choose your census block layer
 - c. Under "that:" choose *have their center in*
 - d. Under "the features in this layer:" choose your site polygon layer
 - e. Make sure the box for "Use selected features" is checked
 - f. Hit "Apply"
4. Open the attribute table of the census block layer.
5. Right-click on the "Hectares" field and select "Statistics".
6. Included in the list of field statistics will be the result of the data calculation for "Mean" (or average) Hectares for the selected study site.
7. Record this number elsewhere (in a spreadsheet or Word file).
8. Repeat steps 2-7 for each study site.

6.2 Median Census Block Area

1. Basic Concept

As with the average census block area, the median block area is an approximation for street pattern where bigger blocks have fewer streets and/or more culs-de sac and unless they also have many additional pedestrian routes they will be harder to get around.

This measure is not as easy to calculate as an average as the calculation needs to be done partly in Excel.

2. Basic Formula

Median Census Block Area = Median area for census blocks with a centroid falling within the measurement geography.

3. Detailed Formula

Same as above.

4. Comments and Explanations

The centroid rule and the inconsistent centroid calculations issues in the previous protocol are the same for this one.

5. GIS Approach

There are two versions of this protocol.

In the first version, the GIS approach is to perform a spatial intersect between the census block centroids and study sites. The attribute table of the resulting layer is imported into Microsoft Access and summarized using the PivotTable feature. This creates a list of all the census blocks whose centroids are in a given study site. The information is imported from Access into Excel where the median area can be calculated automatically.

In the second version, which would work if Microsoft Access was not available for use, the identification of the census block centroids in a study site is done by breaking the study sites into two groups. Sites that do not overlap can be done in one group by selecting the census block centroids and exporting the attributes to Excel for calculating the median area. For sites that do overlap, they must be done one by one, again selecting the census block centroids and exporting to Excel to calculate the median area.

6. GIS Steps

Version 1

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

1. Site layer (polygon)
2. Census block layer (polygon)
3. **XTools** extension (available from the Downloads section of the ESRI website)
4. Microsoft Access
5. Microsoft Excel

The basic steps are:

- Calculate Census Block Areas
- Create Centroid Layer
- Select Census Blocks
- Intersect Census Blocks and Study Sites
- Manipulate output in Access and export to Excel spreadsheet
- Calculate Median Census Block Areas for each Site

Calculate Census Block Areas:

1. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select your new census block layer

- b. Under “Desired output units”, choose your units (depending on the census block size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit “OK”
2. New fields called “Area” and “Hectares” will be created in the attribute table of your new census block layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

Create Centroid Layer:

1. From the XTools drop-down menu, select “Feature Conversions” and choose “Shapes to Centroids”.
2. Under “Select the layer you wish to convert:” select your census block layer.
3. Give the layer a name and click on “OK”.
4. The new layer will be added to your map document.

Select Census Blocks:

1. Add the census block centroid layer and the study site layer to your Map Document.
2. From the “Selection” drop-down menu, choose “Select by Location...”.
3. Under “I want to:” choose “select features from”.
4. Under “the following layers:” select your centroid layer.
5. Under “that” choose “have their center in”.
6. Under “the features in this layer:” select your study site layer.
7. Hit “Apply”. Now the centroids that fall inside your study sites will be selected.
8. From the “Selection” drop-down menu, choose “Select by Location...”.
9. Under “I want to:” choose “select features from”.
10. Under “the following layers:” select your census block centroid layer.
11. Under “that” choose “are completely within”.
12. Under “the features in this layer:” select your study site layer.
13. Hit “Apply”. Now the census blocks centroids that are inside the study sites will be selected.
14. Right click on your census block centroid layer and select “Data” and then “Export Data...”
15. After “Export:” choose selected features.
16. Choose “Use the same Coordinate System as this layer’s source data.”
17. Give the new layer a name and click on OK.
18. When prompted, add the new layer to the Map Document.

Open the GeoProcessing Wizard.

1. Choose *Intersect two layers* and click *Next*
2. Select the exported subset of census block centroids from the previous step as the input layer
3. Select your study site layer as the overlay layer
4. Choose a name and location for the output layer
5. Click *Finish*
6. The new layer will be added to the Map Document

Import data into Microsoft Access

1. Open the Attribute Table of the layer created in the previous intersect step
2. Choose “Export” and select a location and name for the output DBF. NOTE: make the filename 8 characters or less so it can be imported into an Access database.
3. Open Microsoft Access and create a new blank database.
4. Go to File→Get External Data→Import
5. Find the DBF table you exported from ArcMap above and import it
6. Open the newly imported table
7. From the View menu, select PivotTable View
8. In the Field List window, select the name of the unique study site ID and drag it onto the large window where it says “Drop Column Fields Here”

9. From the Field List, drag the field containing the Area onto the large window where it says "Drop Totals or Detail Fields Here"

Copy data into Microsoft Excel and calculate median

1. Open a new blank Microsoft Excel spreadsheet
2. In Access, click and drag the column headings to select them, and then do CTRL-C to copy them
3. Switch to Excel and do CTRL-V to paste them (NOTE: if you have more than 255 study site IDs, you will need to paste into multiple worksheet tabs, as Excel worksheets are limited to 255 columns)
4. Find the row beneath the last row to contain any values (each column will have a different number of values depending on how many census block centroids were found in each measurement geography)
5. Calculate the median of all the cells above containing area values

Version 2

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

6. Site layer (polygon)
7. Census block layer (polygon)
8. **XTools** extension (available from the Downloads section of the ESRI website)

The basic steps are:

- *Create Centroid Layer*
- *Select Census Blocks*
- *Calculate Census Block Areas*
- *Calculate Median Census Block Areas for each Site*

Create Centroid Layer:

5. From the XTools drop-down menu, select "Feature Conversions" and choose "Shapes to Centroids".
6. Under "Select the layer you wish to convert:" select your census block layer.
7. Give the layer a name and click on "OK".
8. The new layer will be added to your map document.

Select Census Blocks:

19. Add the census block layer, the centroid layer, and the study site layer to your Map Document.
20. From the "Selection" drop-down menu, choose "Select by Location...".
21. Under "I want to:" choose "select features from".
22. Under "the following layers:" select your centroid layer.
23. Under "that" choose "have their center in".
24. Under "the features in this layer:" select your study site layer.
25. Hit "Apply". Now the centroids that fall inside your study sites will be selected.
26. From the "Selection" drop-down menu, choose "Select by Location...".
27. Under "I want to:" choose "select features from".
28. Under "the following layers:" select your census block layer.
29. Under "that" choose "contain".
30. Under "the features in this layer:" select your centroid layer.
31. Be sure the button for "Use selected features" is checked.
32. Hit "Apply". Now the census blocks that contain the selected centroids will be selected.
33. Right click on your census block layer and select "Data" and then "Export Data..."
34. After "Export:" choose selected features.
35. Choose "Use the same Coordinate System as this layer's source data."
36. Give the new layer a name and click on OK.
37. When prompted, add the new layer to the Map Document.

Calculate Census Block Areas:

3. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select your new census block layer
 - b. Under "Desired output units", choose your units (depending on the census block size, try *Miles, Meters, or Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Area and Hectares selected)
 - d. Hit "OK"
4. New fields called "Area" and "Hectares" will be created in the attribute table of your new census block layer with the areas of each polygon calculated in the units you chose (Area) and in hectares (Hectares).

Calculate Median Census Block Areas for **multiple non-overlapping Sites**:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using a Spatial Join, assign the IDs from the sites to each census block in the new census block layer.
3. Open the attribute table of the new census block layer.
4. Under the XTools drop-down menu, select "Table Operations" and then "Export to Excel".
5. Under "Select source table:" select your census block layer.
6. Under "Select fields to export:" select the field that contains the IDs and the field labeled "Hectares".
7. Hit "OK".
8. The two fields will be exported into a new Excel worksheet. Use the Excel formula commands to calculate the median size of the census blocks in each study site.

Calculate Median Census Block Areas for **multiple overlapping Sites**:

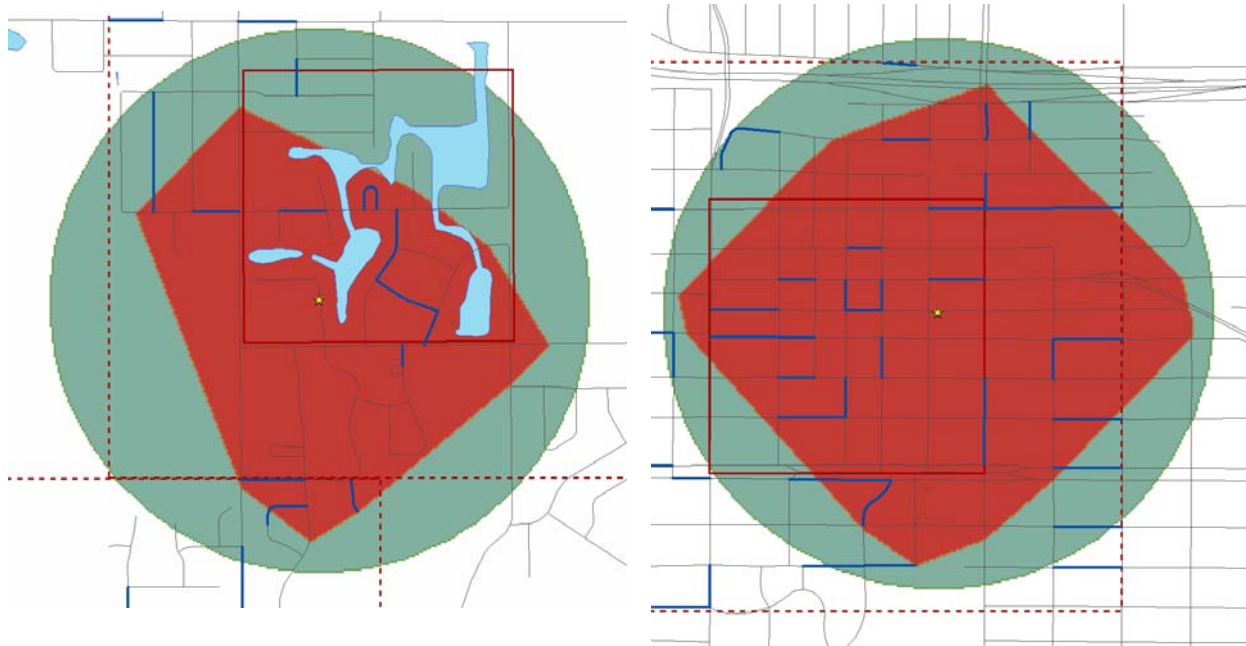
1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using your site polygon layer, select (highlight) the first study site.
3. Perform a "Select By Location".
 - a. Under "I want to:" choose *select features from*
 - b. Under "the following layers:" choose your census block layer
 - c. Under "that:" choose *have their center in*
 - d. Under "the features in this layer:" choose your site polygon layer
 - e. Make sure the box for "Use selected features" is checked
 - f. Hit "Apply"
4. Open the attribute table of the census block layer.
5. Click on the "Show: Selected" button at the bottom of the screen.
6. Under the XTools drop-down menu, select "Table Operations" and then "Export to Excel".
7. Under "Select source table:" select your census block layer.
8. Under "Select fields to export:" select the field labeled "Hectares".
9. Hit "OK".
10. The "Hectares" field will be exported into a new Excel worksheet. Use the Excel formula commands to calculate the median size of the census blocks in the study site.
11. Record this number elsewhere (in a spreadsheet or Word file).
12. Repeat steps 2-11 for each study site.

6.3 Ratio of Area within X Street Distance to Area within X Distance Radius

1. Basic Concept

Also called the effective walking area (Dill 2003) this is a measure of how connected the street pattern is. As can be seen in the diagram below, the area that can be reached along the street

network (the central, red area), is smaller in the loop and cul-de-sac road arrangement than in the more gridded street pattern to the right.



Both diagrams show two 0.5 mile/402 meter buffers—a straight line or crow flies buffer and 0.5 mile/402 meter street distance buffer. The left diagram was generated in an area with many loops and culs-de-sac and the right in a more gridded area with smaller median block size. As can be seen visually, the ratio of the area within a network buffer to area within the crow flies buffer is much smaller in the loop and cul-de-sac area than in the gridded area, indicating that it is harder to get around.

Previous work in this area had looked at the ratio of number of parcels within the network distance to parcels within the crow flies distance (Dill 2003, 5). We, however, decided to look at the areas.

It should be noted that the network buffer diagram shapes generate a set of points along the road network at x distance from the starting point, then join the points. This means that this is an approximation of the area people can walk to as it cuts through large parcels. It also uses the street network rather than the pedestrian network as the base and some researchers think this may be a less accurate measure of pedestrian accessibility in the suburbs where cuts-through parks and parking lots are typical (Moudon 200X). However, as an approximation it seems to be relevant.

2. Basic Formula

Ratio of Area within X Street Distance to Area within X Distance Radius = Ratio of area within a x distance network buffer distance divided by area within a x distance crow flies buffer.

3. Detailed Formula

Ratio of Area within X Street Distance to Area within X Distance Radius = Ratio of area within a x distance network buffer distance divided by area within a x distance crow flies buffer with water excluded from both measures.

4. Comments and Explanations

As was explained in Chapter 2, Network Analyst is currently only available in ArcView so those using ArcGIS will need to use this second program.

5. GIS Approach

Use the Buffer tool to create 400 meter buffers, then use Network Analyst to create the 400 meter network buffers. Use XTools to calculate the area of each buffer and then divide the area of the network buffer by the area of the crow flies buffer.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 9.0 and ArcView 3.3.

To follow this protocol you will need:

1. Site layer (polygon)
2. Participant locations layer (point)
3. Road centerline layer (polyline)
4. **XTools** extension (available from the Downloads section of the ESRI website)

Calculate area of straight line buffers

1. Start an ArcMap 9.0 document and add the participant locations to the view
2. In Arc Toolbox, open *Analysis Tools* → *Proximity*, and select *Buffer*.
3. In the *Buffer* tool window, under *Input Features* select your participant locations layer
4. Under *Output Feature Class*, choose a name and location for the output shapefile
5. For *Distance*, click *Linear Distance*, enter 400, and select meters from the drop-down list
6. Click *OK*
7. From the XTools menu, select “Table Operations” and then “Calculate Area, Perimeter, Length, Acres, and Hectares” (follow instructions included with the extension for XTools installation).
 - a. Under “Select layer to measure”, select the new buffer layer
 - b. Under “Desired output units”, choose your units (depending on the parcel size, try *Meters* or *Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Hectares selected)
 - d. Hit *OK*
8. A field called Hectares will be added to the Attribute Table of the straight line buffer layer.

Calculate area of network buffers

1. Start an ArcView 3.3 project and add the roads layer and participant locations layer to a new view
 - a. Go to the View menu and select Properties to set the map and distance units
 - b. Go to the File menu and select Extensions
 - c. Check the box to turn on the Network Analyst extension
2. Open the participant locations table
3. Go to the Table menu and choose Start Editing
4. Go to the Edit menu and choose Add Field
5. Name the field REPORTCOST and set it to type Number, then hit *OK*
6. Click the heading of the new REPORTCOST field, open the Field menu, and choose Calculate
7. Type 400 and hit *OK*
8. Go to the Table menu and choose Stop Editing, then click Yes when prompted to save edits
9. Select the roads theme in the View
10. Go to the Network menu and choose Find Service Area
11. Click the Load Sites button and choose the participant locations layer
12. Make sure Travel from site is selected
13. Click the button in the upper right of the window with the grid and black arrow to begin the processing
14. When finished, click on the Sarea1 theme in the View

15. Go to the Theme menu and choose Convert to shapefile
16. Select a name and location for the new shapefile
17. Switch to ArcMap and add this new shapefile to the view
18. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select the new network buffer layer
 - b. Under "Desired output units", choose your units (depending on the parcel size, try *Meters* or *Feet*, for example)
 - c. If you do not wish to generate a parameter, such as Perimeter, Length, or Hectares, deselect it now (leave Hectares selected)
 - d. Hit OK
19. A field called Hectares will be added to the Attribute Table of the network buffer layer

For each study site, divide the area of its network buffer by the area of its straight line buffer to calculate the ratio.

6.4 Number of Access Points

1. Basic Concept

Access points are a measure of the amount of connection an area has to its surroundings. We are not convinced it is a good measure of walkability but we are testing it.

At its most extreme one can imagine a gated neighborhood which inside the neighborhood had small blocks and a highly connected street pattern, but had only one way in and out. In this case walking to destinations outside the development would be made far more complex. Access point measures create a measurement geography, generally a grid cell, and measure how porous its edges are (Southworth 1997; McNally and Kulkarni 1997, 109).

2. Basic Formula

Number of Access Points = Number of times a road crosses the edge of the measurement geography.

3. Detailed Formula

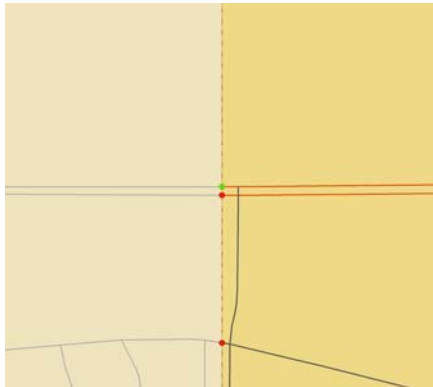
Number of Access Points = Number of times a road crosses the edge of the measurement geography with divided at-grade roads counted once and limited access highways excluded.

4. Comments and Explanations

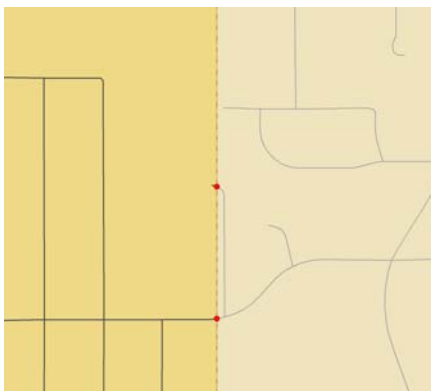


Access points are points of intersection between road centerlines and site boundaries excluding points resulting from the intersections of site boundaries with Interstates, on- and off-ramps, and other limited access highways.

In the diagram to the left, the four green points are access points created by the intersection of the site boundary and an Interstate and its on- and off-ramps, and therefore are excluded from the analysis. The red point is a valid access point.



Also, site boundary intersections with divided at-grade roads, such as parkways, are counted once (as one access point) instead of twice. The green point in the diagram to the left is half of a set of paired access points created by the intersection of the site boundary and a divided parkway. Only the red access points are included in the analysis.



Many access points, as measured, are somewhat marginal in their quality. That is, these points may exist but not provide significant access to the site, or may fall just inside the site boundary and therefore not be counted (see examples below). The red point in the middle of the image is technically an access point because the road centerline just crosses the site boundary, even though it provides no significant access to the site. However, it is extremely complex to develop rules to exclude such points—see next image for more examples.



The three purple circles identify points that should be included in the analysis, since they provide significant access to the site, but are not because the road centerlines lie just inside the site boundary and do not intersect it.

We experimented with methods of buffering these points and derived various rules for exclusion or inclusion, but in the end determined that this opened the door to many subjective decisions. It seemed that the number of access points included that probably should be excluded would roughly offset the number of access points excluded that probably should be included and therefore we decided to set aside the issue of marginal access points in our

analysis.

5. GIS Approach

A point file was created that contained all points where road centerlines intersected site boundaries. From this set, Interstate points were deselected. For any divided roads (those with two distinct centerlines, such as parkways), one half of the access points were deselected. The total number of access points for each study site were summed.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

1. Site layer (polygon)
2. Site boundary layer (polyline)
If you only have a polygon site layer, convert the polygons to polylines using the XTools extension (available from the Downloads section of the ESRI website).
3. Road centerline layer (polyline)
4. AddPointsAtCrossings ArcScript available from the Downloads section of the ESRI website

The basic steps are:

- *Create the Access Point file*
- *Correct for Interstate Access Points*
- *Correct for Parkway Access Points*
- *Remove Unwanted Access Points from View/Table*
- *Summarize Access Point Counts for each Site*

Create the Access Point file:

1. Using ArcMap, install the AddPointsAtCrossings script following the instructions included with the file.
2. Add to your Map Document the road centerline and the site boundary layers.
3. In ArcCatalog, create a point file (layer) that will eventually contain the output of the access point procedure.
4. Begin editing the point layer.
5. Highlight the two polyline layers.
6. Run the AddPointsAtCrossings macro.
7. Your point layer will now contain points created from the intersections of the two polyline layers.

Correct for Interstate Access Points:

1. Open the attribute table of the access point layer.
2. Click on the "Options" button at the bottom of the window and select "Add Field"
3. Enter the field name "Corrected".
4. Hit "OK"
5. In your view, manually select the access points that result from the intersection of a site boundary and an Interstate or its on- or off-ramps.
6. Return to the attribute table of your access point layer.
7. Click on the "Show: Selected" button at the bottom of the screen.
8. Right click on the field name you just created ("Corrected").
9. Select "Calculate Values".
10. Assign these records a value of "1".
11. Click on the "Show: All" button at the bottom of the screen.
12. Click on the "Options" button at the bottom of the screen and select "Clear Selection". Close the attribute table.

Correct for Parkway Access Points:

1. In your view, manually select one of each of the pair of access points resulting from divided parkways.
2. Open the attribute table of the access point layer.
3. Click on the "Show: Selected" button at the bottom of the screen.
4. Right click on the field name you just created ("Corrected").
5. Select "Calculate Values".
6. Assign these records a value of "2".
7. Click on the "Show: All" button at the bottom of the screen.
8. Click on the "Options" button at the bottom of the screen and select "Clear Selection". Close the attribute table.

Remove Unwanted Access Points from View / Table:

1. Right click on your access point layer and select "Properties".
2. Click the tab that says "Definition Query".
3. Click the button that says "Query Builder".
4. Under "Fields" double-click on the field you just created ("Corrected").
5. Click or type "=". Under "Unique Values:" double-click on "0".
6. Hit "OK". The Query Builder window will close.
7. Hit "OK". The Layer Properties window will close.
8. Now, access points resulting from the intersection of a site boundary and an Interstate or its on- and off-ramps and one of the paired divided parkway points will not be displayed. To display all access points again, repeat steps 1-7 but remove the existing equation in the "Query Builder".

Summarize Access Point Counts for **multiple non-overlapping sites without shared edges**:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using a Spatial Join, assign the IDs from the sites to each access point.
3. Open the attribute table of the access point layer and select the field that contains the IDs.
4. Right-click on the field name and select Summarize.
5. Select or create an output file name and hit OK.
6. The output .dbf file will contain the counts of access points in each site.

Summarize Access Point Counts for **multiple non-overlapping sites with shared edges**:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using a Spatial Join, assign the IDs from the site to each access point (use "closest distance" features).
3. Access points that fall on shared edges will each have two records in the attribute table. When joined, both points will be given the same ID. Each shared access point must have one of the two IDs changed manually in the table.
4. Once step 3 is complete, open the attribute table of the access point layer and select the field that contains the IDs.
5. Right-click on the field name and select Summarize.
6. Select or create an output file name and hit OK.
7. The output .dbf file will contain the counts of access points in each site.

Summarize Access Point Counts for **multiple overlapping sites**:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using your site polyline layer, select (highlight) the first study site.
3. Perform a "Select By Location".
4. Under "I want to:" choose *select features from*
5. Under "the following layers:" choose your access point layer
6. Under "that:" choose *are within a distance of*
7. Under "the features in this layer:" choose your site polyline layer
8. Make sure the box for "Use selected features" is checked
9. Check the box for "Apply a buffer...of:" and fill in a very small distance (e.g., 1 meter)
10. Hit "Apply"
11. Open the attribute table of the access point layer.
12. Text at the bottom of the window should show you how many access points are selected. This is the number of access point for the study site you currently have selected.
13. Record this number elsewhere (in a spreadsheet or Word file).
14. Repeat steps 2-6 for each study site.

6.5 Road Length per Unit Area

1. Basic Concept

Road length per hectare is related to both block size and connectivity.

The next version of these protocols will contain more detailed about earlier uses of this measurement.

2. Basic Formula

Road Length per Unit Area = Length of road with both interstates and ramps removed and divided roads averaged, per measurement area.

3. Detailed Formula

Road Length per Unit Area = Length of road with both interstates and ramps removed and divided roads averaged, per measurement area with water removed from land area calculation.

4. Comments and Explanations

Road lengths are simply the sums of the lengths of all road centerlines bounded by the study sites. Similar to the process used for access points, we ignored non-pedestrian lengths by removing Interstates and on- and off-ramps from our calculations. Also, we removed one of each pair of centerlines from all parkways and other divided at-grade roads in order to count their lengths once instead of twice.

Once this was done we used the area of each site to calculate the road length per hectare figures for each site.

5. GIS Approach

Delete all Interstates and on- and off-ramps. Delete one of each pair of centerlines for parkways and at-grade divided roads. Intersect the roads layer with the measurement geographies. Recalculate the length of the road segments. Summarize the intersected layer by the measurement geography ID, calculating the sum of the Length field in the process. Divide the resulting sum of road lengths by the area in hectares of the associated measurement geography.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Site layer (polygon)
2. Road centerline layer (polyline)
3. **XTools** extension (available from the Downloads section of the ESRI website)
4. The protocol for determining **Net Land Area (without water)**

The basic steps are:

- *Calculate Road Lengths*
- *Correct for Interstate Road Segments*
- *Correct for Divided At-grade Road Segments*
- *Remove Unwanted Road Segments from View/Table*
- *Summarize Road Lengths*
- *Determine Net Land Area (without water) for each Site*
- *Calculate Road Length per Hectare*

Calculate Road Lengths:

1. Using the GeoProcessing Wizard, intersect the road centerline layer with the site polygon layer.
 - a. Under the Tools menu, select "GeoProcessing Wizard".
 - b. Select "Intersect Two Layers" and click on "Next".

- c. Under "Select the input layer to intersect:" choose your road layer.
 - d. Under "Select a polygon overlay layer:" choose your site layer.
 - e. Give your file a name and hit "Finish".
2. Using XTools, recalculate the length of the road segments in the newly intersected layer.
 - a. Under the XTools menu, select "Table Operations".
 - b. Choose "Calculate Area, Perimeter, Length, Acres, and Hectares".
 - c. Under "Select layer to measure:" choose your new road layer.
 - d. Choose your desired output units.
 - e. Hit "OK". The lengths of the road segments in the Length field will be recalculated.

Correct for Interstate Road Segments:

1. Open the attribute table of your new road layer (right-click on the layer).
2. Click on the "Options" button at the bottom of the window and select "Add Field"
3. Enter a name for a field that will indicate if a road segment is an Interstate or an on- or off-ramp.
4. Hit "OK"
5. In your view, manually select the road segments that are Interstates or on- or off-ramps.
6. Return to the attribute table of your road layer.
7. Click on the "Show: Selected" button at the bottom of the screen.
8. Right click on the field name you just created.
9. Select "Calculate Values".
10. Assign these records a value of "1".
11. Click on the "Show: All" button at the bottom of the screen.
12. Click on the "Options" button at the bottom of the screen and select "Clear Selection". Close the attribute table.

Correct for Divided At-grade Road Segments:

1. Open the attribute table of your new road layer.
2. Click on the "Options" button at the bottom of the window and select "Add Field"
3. Enter a name for a field that will indicate if a road segment is a divided at-grade road segment.
4. Hit "OK"
5. Click on the "Options" button at the bottom of the window and select "Add Field"
6. Enter a name for a field that will indicate it contains an average length of a divided at-grade road segment.
7. Hit "OK"
8. For each site that contains divided at-grade road segments, select the pair of roadways that make up the divided at-grade road.
9. Return to the attribute table of your road layer.
10. Click on the "Show: Selected" button at the bottom of the screen.
11. Right click on the field name you just created.
12. Select "Calculate Values".
13. Assign these records a value of "1".
14. Calculated the total length of the two roadways.
15. Divide by 2 to find the average length.
16. Enter this length into the new AVERAGE field of any one record of those currently selected (leave the remained selected records as 0).
17. Repeat steps 8-16 for each set of divided at-grade roads in the site.
18. Repeat steps 8-17 for each site.

Remove Unwanted Road Segments from View/Table:

1. Right click on your access point layer and select "Properties".
2. Click the tab that says "Definition Query".
3. Click the button that says "Query Builder".
4. Under "Fields" double-click on the field you just created for Interstates and on- and off-ramps.
5. Click or type "=". Under "Unique Values:" double-click on "0".
6. Hit "OK". The Query Builder window will close.
7. Hit "OK". The Layer Properties window will close.

8. Now, only those road segments that are NOT Interstates or on- and off-ramps will be displayed. To display all road segments again, repeat steps 1-7 but remove the existing equation in the "Query Builder".

Summarize Road Lengths:

1. Open the attribute table of the new roads layer.
2. Click on the "Options" button at the bottom of the window and select "Select by Attributes".
3. Under "Fields" double-click on the field you created for divided at-grade roadways.
4. Click or type "=". Under "Unique Values:" double-click on "0".
5. Hit "Apply". (You may now close the "Select by Attributes" window at any time.)
6. Click on the "Show: Selected" button at the bottom of the screen. Only the non-divided road segments will now be displayed.
7. Right-click on the ID field name and select Summarize.
8. In the window that opens, under step 2 select the Length field and check the box marked sum.
9. Select or create an output file name and hit OK.
10. At the bottom of the window check the box marked "Summarize on the selected records only".
11. The output .dbf file will contain the sums of the lengths of non-divided roads in each site.
12. Click on the "Options" button at the bottom of the window and select "Switch selection". The divided road segments will now be selected.
13. Click on the "Show: Selected" button at the bottom of the screen. Only the divided road segments will now be displayed.
14. Right-click on the ID field name and select Summarize.
15. In the window that opens, under step 2 select the Average Length field and check the box marked sum.
16. Select or create an output file name and hit OK.
17. At the bottom of the window check the box marked "Summarize on the selected records only".
18. The output .dbf file will contain the sums of the average lengths of divided roads in each site.
19. In Excel or other spreadsheet program, open the two .dbf files and sum the road lengths to arrive at the total road lengths for each site.

Determine Net Land Area (without water) for each Site:

1. Follow the steps outlined in the protocol above.

Calculate Road Length per Hectare:

1. Open the attribute table of the site layer and right click on the ID field name. Select Summarize.
2. In the window that opens, under step 2 select the Hectares field and check the box marked sum.
3. Select or create an output file name and hit OK.
4. The output .dbf file will contain the total hectares in each site.
5. In Excel or other spreadsheet program, combine your total road length figures and your total hectares figures based on the site ID numbers.
6. For each site, divide total road length by total hectares to arrive at road length per hectare figures.

6.6 Intersections per Unit Area

1. Basic Concept

The number of intersections per hectare is a measure of the connectivity of the street network (Cervero and Kockelman 1996, 8; McNally and Kulkarni 1997, 109). However, as can be seen from this and later protocols, judging an intersection can be complex, particularly in older areas in particular, where intersections are not regularly spaced, road rights of way have varying sizes, and centerlines may be slightly offset within the right of way creating false positives in terms of intersection counts (see below for more detail).

This is obviously an area where more research would help, to discover how much of a jog in an intersection is needed before it is perceived as two intersections. In the absence of such research, we spent some time observing difficult cases in the field.

2. Basic Formula

Intersections per Unit Area = Number of intersections per unit land area.

3. Detailed Formula

Intersections per Unit Area = Number of intersections per unit land area excluding freeways with land area excluding water. Intersections are measured raw, and buffered by 10 meter and 15 meter buffers to deal with slightly offset centerlines and divided roads.

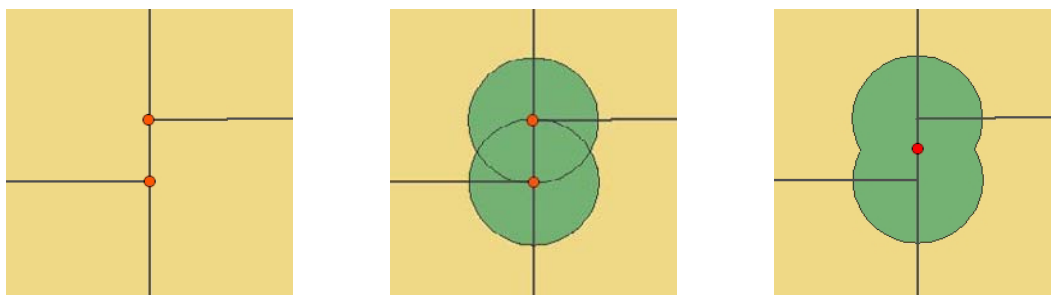
4. Comments and Explanations

As was explained in the introduction to this chapter, a key issue in measuring intersections is how the streets are entered into the GIS database—as a series of segments that end at each intersection or as long lines that overlap. These instructions are for the segment-by-segment type of database—other types will need to use slightly different ArcGIS operations although the concepts will be basically the same.



All of our intersection counts excluded intersections formed by the convergence of Interstates and on- or off-ramps (see diagram to left), but included intersections between on- and off-ramps and local streets.

We also tried to correct for intersections where roads converged on an area but did not perfectly align and therefore failed to provide our GIS operations with a single intersection point. To do this, we created buffers around each intersection point (both 10 meter and 15 meter buffers), merged them where they overlapped, and created new centroids to act as intersection points for our new intersection polygons (see diagrams below).



This diagram shows the buffering process where two road centerlines are slightly offset, creating two T intersections in the GIS measurement but in the field, because the road has a width on either side of the center line, they would be perceived as one 4-way intersection. In these cases we used buffering to merge the two intersections into one.

A buffer distance of 20 meters was also tried, but it was determined through fieldwork by the environmental measurement team, and then independently by the Principal Investigator, that the distance between roads was too great to consider the area as a singular functional intersection. In order to make these judgments we took two field trips. First, the environmental team walked key intersections at the university and measured them to get a sense of road dimensions. Second, the Principal Investigator located part of the study area with nearby intersections that were 20 (10 meter buffers), 30, and 40 meters apart and went out on a sunny afternoon and observed how walkers were using the intersections. The first two functioned as one intersection, the last did not, although the specific case could vary with the width of the paved areas, the presence or absence of sidewalks, and the location of street trees.)

5. GIS Approach

Remove Interstates from the road centerline file. Use the Calculate Fnode Tnode script to create the intersection point file. Remove points with a valence of 1 or 2. Buffer intersections with 10 and 15 meter buffers and create new intersection centroids. Intersect point file with measurement geography and summarize intersection counts per unit area.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Site layer (polygon)
2. Road centerline layer (polyline)
3. **Calculate Fnode Tnode** ArcScript available from the Downloads section of the ESRI website
4. **XTools** extension (also available from the Downloads section of the ESRI website)
5. The protocol for determining **Net Land Area (without water)**

The basic steps are:

- *Create the Intersections file*
- *Clip Intersections to Study Sites*
- *Correct for Interstate/Ramp Intersections*
- *Remove Unwanted Intersection from View/Table*
- *Create Buffered Intersections*
- *Summarize Intersection Counts for each Site*
- *Determine Net Land Area (without water) for each Site*
- *Calculate Intersections per Hectare for each Site*

Create the Intersections file:

1. Using ArcMap, install the Calculate Fnode Tnode script following the instructions included with the file.
2. Add to your Map Document the road centerline layer.
3. Create a point file (layer) that will eventually contain the output of the intersection node procedure.
4. Run the Calculate Fnode Tnode tool.
5. When prompted, select your road centerline layer as your polyline layer and the new point layer as your point layer.
6. Select 0 as the beginning ID number for the nodes.

7. After the procedure concludes, your point layer will now contain points created from the nodes of the road centerline layer. The numbers in the "valence" field represent the number of roads that converge to create the node (e.g., a valence of 1 means the node is a dead end or cul-de-sac; a valence of 3 indicates a 3-way intersection; etc.).

Clip Intersections to Study Sites:

1. Using GeoProcessing Wizard, clip the intersection layer to your study site(s).
 - a. In the GeoProcessing Wizard, select *Clip one layer based on another*
 - b. Click on *Next*
 - c. Under *Select the input layer to clip*, select your intersection layer
 - d. Under *Select a polygon clip layer*, select your study site layer
 - e. Give your clipped layer a name and click on *Finish*
2. The new clipped layer will open separately.

Correct for Interstate/Ramp Intersections:

1. Open the attribute table of the (clipped) intersection layer.
2. Click on the "Options" button at the bottom of the window and select "Add Field"
3. Enter the field name "Corrected".
4. Hit "OK"
5. In your view, manually select the intersections formed by the convergence of Interstates and on- or off-ramps.
6. Return to the attribute table of your intersection layer.
7. Click on the "Show: Selected" button at the bottom of the screen.
8. Right click on the field name you just created ("Corrected").
9. Select "Calculate Values".
10. Assign these records a value of "1".
11. Click on the "Show: All" button at the bottom of the screen.
12. Click on the "Options" button at the bottom of the screen and select "Clear Selection". Close the attribute table.

Remove Unwanted Intersections from View/Table:

1. Right click on your intersection layer and select "Properties".
2. Click the tab that says "Definition Query".
3. Click the button that says "Query Builder".
4. Under "Fields" double-click on the field you just created ("Corrected").
5. Click or type "=". Under "Unique Values:" double-click on "0".
6. Click or type "AND".
7. Under "Fields" double-click on "valence".
8. Click or type ">". Under "Unique Values:" double-click on "2".
9. Hit "OK". The Query Builder window will close.
10. Hit "OK". The Layer Properties window will close.
11. Now, only those intersections NOT formed by the convergence of Interstates and on- or off-ramps AND created by the intersection of 3 or more road segments (no cul-de-sacs) will be displayed. To display all intersections again, repeat steps 1-10 but remove the existing equation in the "Query Builder".

Create Buffered Intersections:

1. Under the Tools dropdown menu, select "Buffer wizard".
 - a. In the Buffer Wizard window, under "The features of a layer" select your (clipped) intersection layer and click on *Next*
 - b. Click "At a specified distance" and enter XX (your desired distance)
 - c. After "Distance units are:" select *meters*
 - d. Click *Next*
 - e. After "Dissolve barriers between" select *Yes*
 - f. Give the layer a name and save as a new layer
 - g. Click *Finish*

2. Using XTools, select “Feature Conversions” and then “Shapes to Centroids”.
 - a. Select the new buffer layer (polygon)
 - b. Give the point layer you are about to create a name and click OK
3. The new layer will contain points that represent merged intersections – those resulting from two intersections that are within 2(XX) meters of each other (a XX meter radius around each intersection) and essentially functioning as one intersection for the purposes of this analysis.

Summarize Intersection Counts for multiple non-overlapping sites:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using a Spatial Join, assign the IDs from the sites to each intersection.
3. Open the attribute table of the intersection layer and select the field that contains the IDs.
4. Right-click on the field name and select Summarize.
5. Select or create an output file name and hit OK.
6. The output .dbf file will contain the counts of intersection nodes in each site.

Summarize Intersection Counts for multiple overlapping sites:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using your site polygon layer, select (highlight) the first study site.
3. Perform a “Select By Location”.
 - a. Under “I want to:” choose *select features from*
 - b. Under “the following layers:” choose your intersection node layer
 - c. Under “that:” choose *have their center in*
 - d. Under “the features in this layer:” choose your site polygon layer
 - e. Make sure the box for “Use selected features” is checked
 - f. Hit “Apply”
4. Open the attribute table of the intersection node layer.
5. Text at the bottom of the window should show you how many intersections are selected. This is the number of intersections in the study site you currently have selected.
6. Record this number elsewhere (in a spreadsheet or Word file).
7. Repeat steps 2-6 for each study site.

Determine Net Land Area (without water) for each Site:

1. Follow the steps outlined in the protocol above.

Calculate Intersections per Hectare for each Site:

1. Open the attribute table of the site layer and right click on the ID field name. Select Summarize.
2. In the window that opens, under step 2 select the Hectares field and check the box marked sum.
3. Select or create an output file name and hit OK.
4. The output .dbf file will contain the total hectares in each site.
5. In Excel or other spreadsheet program, combine intersection node counts and your total hectares figures based on the site ID numbers.
6. For each site, divide the number of intersection nodes by total hectares to get the number of intersections per hectare.

6.7 Ratio of 4-Way Intersections to All Intersections

1. Basic Concept

Four-way intersections are an indicator of grid street patterns, thought to be more connected. However, one can imagine a high proportion of four way intersections in an area with enormous blocks, so the density of intersections should also be considered.

2. Basic Formula

Ratio of 4-Way Intersections to All Intersections = Raw percent of 4-way intersections versus other intersections (valence 3+).

3. Detailed Formula

Ratio of 4-Way Intersections to All Intersections = Same as above although with the added complication that some higher valence intersections are actually 3-way and 4-way intersections.

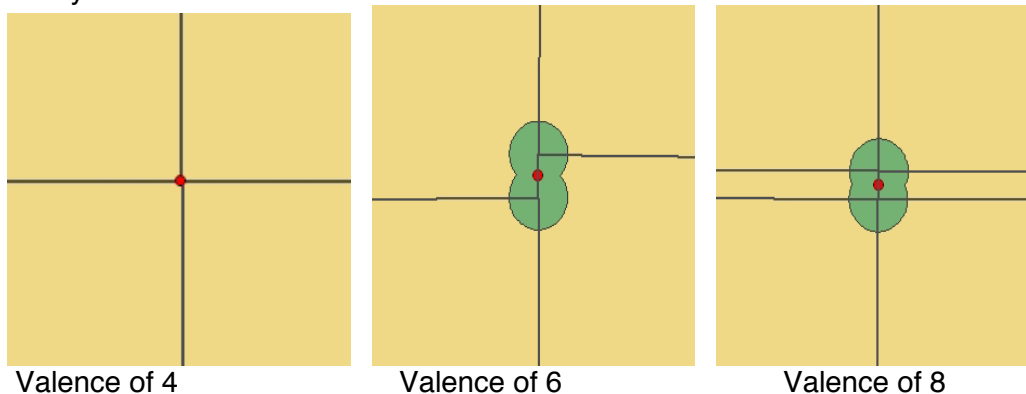
4. Comments and Explanations

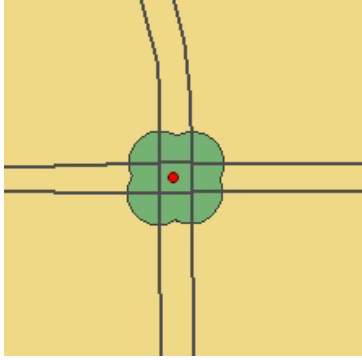
As outlined in Intersections per Unit Area, intersection counts in our study sites (1) did not include intersections formed by the convergence of Interstates and on- or off-ramps and (2) corrected for mis-aligned intersections by creating buffers around each intersection node, merging them where they overlapped, and creating a centroid for each new intersection polygon.

In order to be able to classify these new nodes, we created “rules” to assign types (3-way, 4-way) to the intersections. These assignments were based on the sum of the valences of the original intersections (the valence of an intersection, based on the script that creates the intersection nodes, is the count of the number of road segments that converge to create the node – a valence of 1 is a dead end or cul-de-sac; a valence of 3 is a 3-way intersection; a valence of 4 is a 4-way intersection; etc.).

In particular, we realized that intersections with valences of 6 were typically the result of two intersections that were not quite aligned but that functioned as 4-way intersections. Intersections with valences of 8 were almost always the result of intersections of divided and non-divided roads that functioned as 4-way intersections. Intersections with valences of 16 were the result of intersections of two divided roads that functioned as 4-way intersections.

4-way intersections:

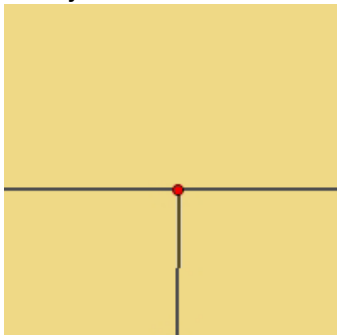




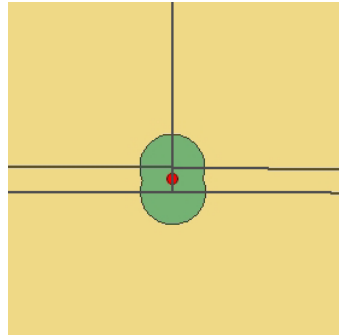
Valence of 16

Likewise, we found that most newly formed intersections with valences of 7 were the result of 3-way intersections of divided and non-divided roads. Similarly, about half of the intersections with valences of 12 were the result of 3-way intersections of two divided roads. These seemed to function as 3-way intersections.

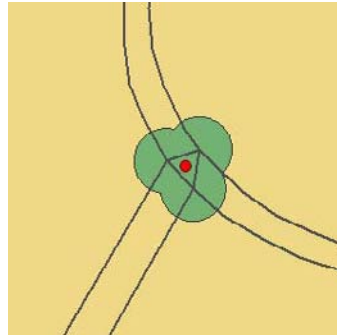
3-way intersections:



Valence of 3

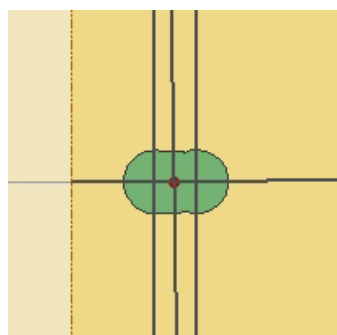
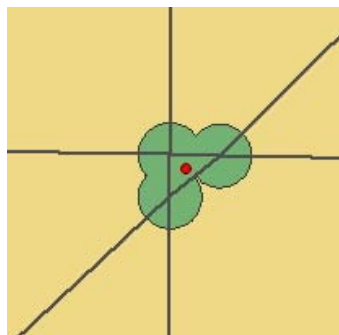
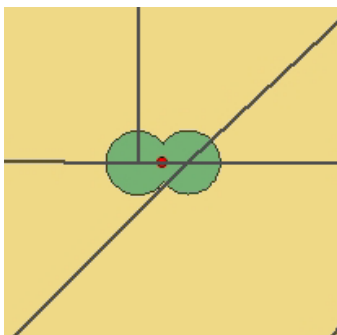


Valence of 7



Valence of 12

There were some intersections with valences of 7 and 12 that did not conform. Specifically, there were a handful of merged intersections with valences of 7 and 12 that were the formed by the convergence of the gridded street pattern with a diagonal. In addition, there was one intersection with a valence of 12 that seemed to function more like a 4-way intersection. Because there were only three intersections of valence 12 using 10 meter buffers (two 3-way and one 4-way) and five using 15 meter buffers (two 3-way and three 4-way), we chose to apply our 3-way and 4-way intersection rules by hand instead of using a blanket rule. The images below were classed as 4-way.

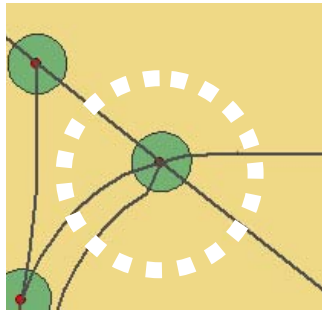


Valence of 7(b)

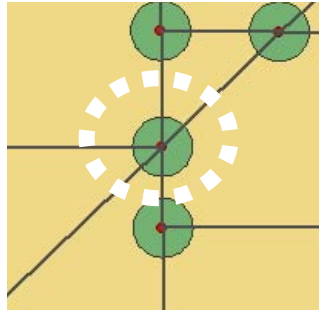
Valence of 12(b)

Valence of 12(c)

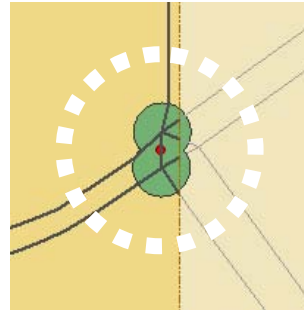
Finally, there were a number of other new intersection types that were more complex than either 3-way or 4-way intersections. These were partly an artifact of our trying to deal with classifying functional 3- and 4- way intersections, through buffering. These are intersections that show a high level of connectivity which is the point of the 4-way intersection count, so they were counted as 4 way intersections. **Note, the intersection being referred to is outlined with a dotted oval.**



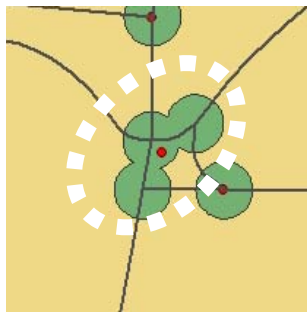
Valence of 5(a)



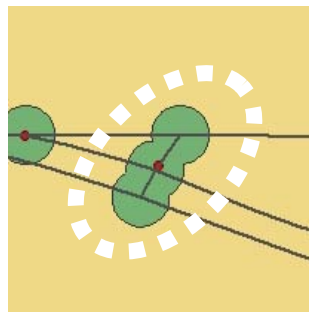
Valence of 5(b)



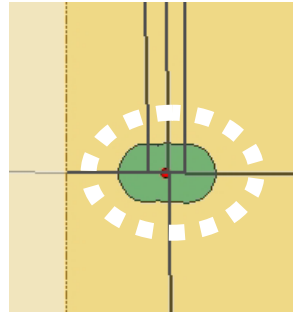
Valence of 9 (should really be 13)



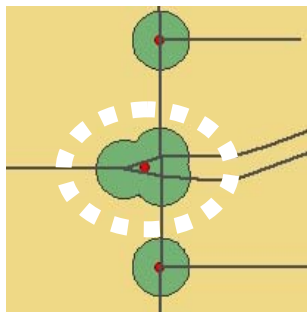
Valence of 10(a)



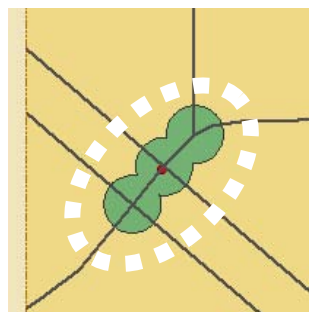
Valence of 10(b)



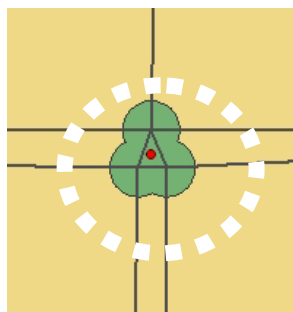
Valence of 10(c)



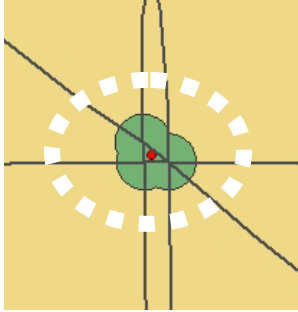
Valence of 11(a)



Valence of 11(b)



Valence of 13



Valence of 14

For all our intersection counts, we ran our numbers three times. During the first run, we counted intersections without any buffers. During the second run, we counted intersections that were buffered 10 meters and adjusted for valences of 6, 7, 8, 12, and 16 and other adjustments as detailed above. Finally, in our third run, we counted intersections that were buffered 15 meters and adjusted for valences of 6, 7, 8, 12, and 16 and other adjustments as detailed above.

5. GIS Approach

Remove Interstates from the road centerline file. Use the Calculate Fnode Tnode script to create the intersection point file. Remove points with a valence of 1 or 2. Buffer intersections with 10 and 15 meter buffers and create new intersection centroids with reassigned valences. Intersect point file with measurement geography and calculate ratios of 4-way intersection counts to total intersection counts.

6. GIS Steps [Note: These need to be adjusted for valences over 4.]

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

5. Site layer (polygon)
6. Road centerline layer (polyline)
7. Intersection node layer (point)
8. **Calculate Fnode Tnode** ArcScript available from the Downloads section of the ESRI website
9. **XTools** extension (also available from the Downloads section of the ESRI website)
10. *Total intersection counts* from protocol for calculating **Intersections per Unit Area**

The basic steps are:

- *Create the Intersections file*
- *Clip Intersections to Study Sites*
- *Correct for Interstate/Ramp Intersections*
- *Remove Unwanted Intersections from View/Table*
- *Create Buffered Intersections*
- *Assign New Valences to Buffered Intersections*
- *Summarize 4-way Intersection Counts for each Site*
- *Calculate 4-way Intersection Ratios for each Site*

Create the Intersections file:

1. Using ArcMap, install the Calculate Fnode Tnode script following the instructions included with the file.
2. Add to your Map Document the road centerline layer.
3. Create a point file (layer) that will eventually contain the output of the intersection node procedure.

4. Run the Calculate Fnode Tnode tool.
5. When prompted, select your road centerline layer as your polyline layer and the new point layer as your point layer.
6. Select 0 as the beginning ID number for the nodes.
7. After the procedure concludes, your point layer will now contain points created from the nodes of the road centerline layer. The numbers in the "valence" field represent the number of roads that converge to create the node (e.g., a valence of 1 means the node is a dead end or cul-de-sac; a valence of 3 indicates a 3-way intersection; etc.).

Clip Intersections to Study Sites:

1. Using GeoProcessing Wizard, clip the intersection layer to your study site(s).
2. In the GeoProcessing Wizard, select *Clip one layer based on another*
3. Click on *Next*
4. Under *Select the input layer to clip*, select your intersection layer
5. Under *Select a polygon clip layer*, select your study site layer
6. Give your clipped layer a name and click on *Finish*
7. The new clipped layer will open separately.

Correct for Interstate/Ramp Intersections:

1. Open the attribute table of the (clipped) intersection layer.
2. Click on the "Options" button at the bottom of the window and select "Add Field"
3. Enter the field name "Corrected".
4. Hit "OK"
5. In your view, manually select the intersections formed by the convergence of Interstates and on- or off-ramps.
6. Return to the attribute table of your intersection layer.
7. Click on the "Show: Selected" button at the bottom of the screen.
8. Right click on the field name you just created ("Corrected").
9. Select "Calculate Values".
10. Assign these records a value of "1".
11. Click on the "Show: All" button at the bottom of the screen.
12. Click on the "Options" button at the bottom of the screen and select "Clear Selection". Close the attribute table.

Remove Unwanted Intersections from View/ Table:

1. Add the intersection layer to your Map Document.
2. Right click on the intersection layer and select "Properties".
3. Click the tab that says "Definition Query".
4. Click the button that says "Query Builder".
5. Under "Fields" double-click on the field "Corrected".
6. Click or type "=". Under "Unique Values:" double-click on "0".
7. Click or type "AND".
8. Under "Fields" double-click on "valence".
9. Click or type ">". Under "Unique Values:" double-click on "2".
10. Hit "OK". The Query Builder window will close.
11. Hit "OK". The Layer Properties window will close.
12. Now, only those intersections NOT formed by the convergence of Interstates and on- or off-ramps AND created by the intersection of 3 or more road segments (no cul-de-sacs) will be displayed. To display all intersections again, repeat steps 1-10 but remove the existing equation in the "Query Builder".

Create Buffered Intersections:

1. Under the Tools dropdown menu, select "Buffer wizard".
2. In the Buffer Wizard window, under "The features of a layer" select your (clipped) intersection layer and click on *Next*
3. Click "At a specified distance" and enter XX (your desired distance)

4. After "Distance units are:" select *meters*
5. Click *Next*
6. After "Dissolve barriers between" select *Yes*
7. Give the layer a name and save as a new layer
8. Click *Finish*
9. Using XTools, select "Feature Conversions" and then "Shapes to Centroids".
10. Select the new buffer layer (polygon)
11. Give the point layer you are about to create a name and click *OK*
12. The new layer will contain points that represent merged intersections – those resulting from two intersections that are within 2(XX) meters of each other (a XX meter radius around each intersection) and essentially functioning as one intersection for the purposes of this analysis.

Assign New Valences to Buffered Intersections:

1. Perform a Spatial Join on your new buffer layer
 - a. Right click on your new layer and select *Joins and Relates* and then *Join...*
 - b. Under "What do you want to join to this layer?" select *Join data from another layer based on spatial location*
 - c. Under "1. Choose the layer to join to this layer" select your clipped intersection layer (point)
 - d. Under "2. You are joining:" select the first option *Each polygon will be given a summary...*
 - e. Under "How do you want the attributes to be summarized?" check the box for *Sum*
 - f. Under "3. The result of the join will be saved..." give your new layer a name
 - g. Click on *OK*
2. Open the attribute table of your new layer and remove all fields except *Count_* and *Sum_valenc* (TIP: use XTools for multiple-field deletes)
3. Perform a Spatial Join on your centroid layer (created in the previous step)
 - a. Right click on your centroid layer and select *Joins and Relates* and then *Join...*
 - b. Under "What do you want to join to this layer?" select *Join data from another layer based on spatial location*
 - c. Under "1. Choose the layer to join to this layer" select your newly joined buffer layer
 - d. Under "2. You are joining:" select the first option *it fall inside*
 - e. Under "3. The result of the join will be saved..." give your new layer a name
 - f. Click on *OK*
4. Open the attribute table of your new layer and remove all fields except *Count_* and *Sum_valenc*.
5. Click on the "Options" button at the bottom of the screen and select "Add Field..."
6. Give your field the name "New_valenc" and click on *OK*.
7. Right click on "New_valenc" and select "Calculate Values..."
8. Double-click on "Sum_valenc" and click on *OK*. The values from the *Sum_valenc* field will have been copied over to the *New_valenc* field.
9. Click on the "Options" button and select "Select by Attributes".
10. Set "Count" > 1.
11. Click on "Apply".
12. Click on the "Show: Selected" button at the bottom of the screen.
13. Click on the "Options" button and select "Select by Attributes" (this window may still be open).
14. After "Method:" select *Select from current selection*.
15. Set "Sum_valenc" = 6.
16. Right click on "New_valenc" and select "Calculate Values..."
17. Enter 4 in the box below "New_valenc =" and click on *OK*.
18. Repeat steps 9 through 17 twice using "Sum_valenc" = 8 and = 16 in step 15.
19. Click on the "Show: All" button at the bottom of the screen.
20. Click on the "Options" button at the bottom of the screen and select "Clear Selection".
21. Right click on the layer and select "Properties..."
22. Click the tab that says "Definition Query".
23. Click the button that says "Query Builder".
24. Under "Fields" double-click on the field "New_valenc".
25. Click or type "=". Under "Unique Values:" double-click on "4".

26. Hit "OK". The Query Builder window will close.
27. Hit "OK". The Layer Properties window will close.
28. Now, only those intersections with a valence of 4 (four-way intersections) will be displayed. To display all intersections again, repeat steps 21-27 but remove the existing equation in the "Query Builder".

Summarize 4-way Intersection Counts for multiple non-overlapping sites:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using a Spatial Join, assign the IDs from the sites to each intersection.
3. Open the attribute table of the intersection layer and select the field that contains the IDs.
4. Right-click on the field name and select Summarize.
5. Select or create an output file name and hit OK.
6. The output .dbf file will contain the counts of intersection nodes in each site.

Summarize 4-way Intersection Counts for multiple overlapping sites:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using your site polygon layer, select (highlight) the first study site.
3. Perform a "Select By Location".
4. Under "I want to:" choose *select features from*
5. Under "the following layers:" choose your intersection node layer
6. Under "that:" choose *have their center in*
7. Under "the features in this layer:" choose your site polygon layer
8. Make sure the box for "Use selected features" is checked
9. Hit "Apply"
10. Open the attribute table of the intersection node layer.
11. Text at the bottom of the window should show you how many intersections are selected. This is the number of intersections in the study site you currently have selected.
12. Record this number elsewhere (in a spreadsheet or Word file).
13. Repeat steps 2-6 for each study site.

Calculate 4-way Intersection Ratios for each Site

1. In a spreadsheet program such as Excel, open the file containing the summary of total intersection counts for each site created in protocol for **Intersections per Unit Area**.
2. Open the file containing the summary of 4-way intersection counts for each site.
3. Divide the numbers of 4-way intersections by the total numbers of intersections to get the 4-way intersection ratios for each site.

6.8 4-way Intersections per Unit Land Area

1. Basic Concept

Four-way intersections are an indicator of grid street patterns, thought to be supportive for walking. The measure of 4-way intersections per hectare adjusts this measure to reflect different block sizes.

2. Basic Formula

4-way Intersections per Unit Land Area = Number of 4-way intersections per unit land area.

3. Detailed Formula

4-way Intersections per Unit Land Area = Number of 4-way intersections per unit land area excluding water where 4-way intersections are defined as defined in the comments and explanations.

4. Comments and Explanations

For a discussion of what we counted as 4-way intersections see the previous protocol on the Ratio of 4-way Intersections to all Intersections.

5. GIS Approach

For each study site, the 4-way intersection counts were matched to the net land area through the site ID numbers. The intersection counts were divided by the net hectares to get the number of 4-way intersections per hectares for each study site.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. *4-way intersection counts* from protocol for calculating **Ratio of 4-way Intersections to all Intersections**
2. The protocol for determining **Net Land Area (without water)**

The basic steps are:

- *Determine Net Land Area (without water) for each Site*
- *Calculate 4-way Intersections per Hectare for each Site*

Determine Net Land Area (without water) for each Site:

1. Follow the steps outlined in the protocol above.

Calculate 4-Way Intersections per Hectare for each Site:

1. In Excel or other spreadsheet program, combine the 4-way intersection counts and your net land area figures based on the site ID numbers.
2. For each site, divide the number of 4-way intersections by net hectares to get the number of 4-way intersections per hectares.

6.9 Ratio of 3-way Intersections to All Intersections

1. Basic Concept

This is another take on the issue of street connections.

2. Basic Formula

Ratio of 3-way Intersections to All Intersections = Raw percent of 3-way intersections versus other intersections (valence 3+).

3. Detailed Formula

Same as above except to note that some higher valence intersections were reclassified as 3-way if that is how they operated i.e. some valences of 7 and of 12. Buffering was at both 10 and 15 meters.

4. Comments and Explanations

As outlined in Intersections per Unit Area, intersection counts in our study sites (1) did not include intersections formed by the convergence of Interstates and on- or off-ramps and (2) corrected for mis-aligned intersections by creating buffers around each intersection node, merging them where they overlapped, and creating a centroid for each new intersection polygon.

In order to be able to classify these new nodes, we created “rules” to assign types (3-way, 4-way) to the intersections. And are described above in the protocol on the Ratio of 4-way Intersections to all Intersections.

For our intersection ratios, we ran our numbers three times. During the first run, we counted intersections without any buffers. During the second run, we counted buffered intersections, but did not adjust for new valence figures (therefore, a valence of 7 resulting from the intersection of roads with valences of 3 and 4 would remain a valence of 7). Finally, in our third run, we included some valences of both 7 and of 12 in our count of 3-way intersections.

5. GIS Approach

Remove Interstates from the road centerline file. Use the Calculate Fnode Tnode script to create the intersection point file. Remove points with a valence of 1 or 2. Buffer intersections with 10 and 15 meter buffers and create new intersection centroids with reassigned valences. Intersect point file with measurement geography and calculate ratios of 3-way intersection counts to total intersection counts.

6. GIS Steps [Also check this for manual corrections to valence=7 and =12]

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Site layer (polygon)
2. Road centerline layer (polyline)
3. Intersection node layer (point)
4. **Calculate Fnode Tnode** ArcScript available from the Downloads section of the ESRI website
5. **XTools** extension (also available from the Downloads section of the ESRI website)
6. *Total intersection counts* from protocol for calculating **Intersections per Unit Area**

The basic steps are:

- *Create the Intersections file*
- *Clip Intersections to Study Sites*
- *Correct for Interstate/Ramp Intersections*
- *Remove Unwanted Intersections from View/Table*
- *Create Buffered Intersections*
- *Assign New Valences to Buffered Intersections*
- *Summarize 3-way Intersection Counts for each Site*
- *Calculate 3-way Intersection Ratios for each Site*

Create the Intersections file:

1. Using ArcMap, install the Calculate Fnode Tnode script following the instructions included with the file.
2. Add to your Map Document the road centerline layer.
3. Create a point file (layer) that will eventually contain the output of the intersection node procedure.
4. Run the Calculate Fnode Tnode tool.
5. When prompted, select your road centerline layer as your polyline layer and the new point layer as your point layer.
6. Select 0 as the beginning ID number for the nodes.
7. After the procedure concludes, your point layer will now contain points created from the nodes of the road centerline layer. The numbers in the “valence” field represent the number of roads that converge to create the node (e.g., a valence of 1 means the node is a dead end or cul-de-sac; a valence of 3 indicates a 3-way intersection; etc.).

Clip Intersections to Study Sites:

1. Using GeoProcessing Wizard, clip the intersection layer to your study site(s).
2. In the GeoProcessing Wizard, select *Clip one layer based on another*
3. Click on *Next*
4. Under *Select the input layer to clip*, select your intersection layer
5. Under *Select a polygon clip layer*, select your study site layer
6. Give your clipped layer a name and click on *Finish*
7. The new clipped layer will open separately.

Correct for Interstate/Ramp Intersections:

1. Open the attribute table of the (clipped) intersection layer.
2. Click on the "Options" button at the bottom of the window and select "Add Field"
3. Enter the field name "Corrected".
4. Hit "OK"
5. In your view, manually select the intersections formed by the convergence of Interstates and on- or off-ramps.
6. Return to the attribute table of your intersection layer.
7. Click on the "Show: Selected" button at the bottom of the screen.
8. Right click on the field name you just created ("Corrected").
9. Select "Calculate Values".
10. Assign these records a value of "1".
11. Click on the "Show: All" button at the bottom of the screen.
12. Click on the "Options" button at the bottom of the screen and select "Clear Selection". Close the attribute table.

Remove Unwanted Intersections from View/Table:

1. Add the intersection layer to your Map Document.
2. Right click on the intersection layer and select "Properties".
3. Click the tab that says "Definition Query".
4. Click the button that says "Query Builder".
5. Under "Fields" double-click on the field "Corrected".
6. Click or type "=". Under "Unique Values:" double-click on "0".
7. Click or type "AND".
8. Under "Fields" double-click on "valence".
9. Click or type ">". Under "Unique Values:" double-click on "2".
10. Hit "OK". The Query Builder window will close.
11. Hit "OK". The Layer Properties window will close.
12. Now, only those intersections NOT formed by the convergence of Interstates and on- or off-ramps AND created by the intersection of 3 or more road segments (no cul-de-sacs) will be displayed. To display all intersections again, repeat steps 1-10 but remove the existing equation in the "Query Builder".

Create Buffered Intersections:

1. Under the Tools dropdown menu, select "Buffer wizard".
2. In the Buffer Wizard window, under "The features of a layer" select your (clipped) intersection layer and click on *Next*
3. Click "At a specified distance" and enter XX (your desired distance)
4. After "Distance units are:" select *meters*
5. Click *Next*
6. After "Dissolve barriers between" select *Yes*
7. Give the layer a name and save as a new layer
8. Click *Finish*
9. Using XTools, select "Feature Conversions" and then "Shapes to Centroids".
10. Select the new buffer layer (polygon)
11. Give the point layer you are about to create a name and click *OK*

12. The new layer will contain points that represent merged intersections – those resulting from two intersections that are within 2(XX) meters of each other (a XX meter radius around each intersection) and essentially functioning as one intersection for the purposes of this analysis.

Assign New Valences to Buffered Intersections:

1. Perform a Spatial Join on your new buffer layer
 - a. Right click on your new layer and select *Joins and Relates* and then *Join...*
 - b. Under “What do you want to join to this layer?” select *Join data from another layer based on spatial location*
 - c. Under “1. Choose the layer to join to this layer” select your clipped intersection layer (point)
 - d. Under “2. You are joining:” select the first option *Each polygon will be given a summary...*
 - e. Under “How do you want the attributes to be summarized?” check the box for *Sum*
 - f. Under “3. The result of the join will be saved...” give your new layer a name
 - g. Click on OK
2. Open the attribute table of your new layer and remove all fields except Count_ and Sum_valenc (TIP: use XTools for multiple-field deletes)
3. Perform a Spatial Join on your centroid layer (created in the previous step)
 - a. Right click on your centroid layer and select *Joins and Relates* and then *Join...*
 - b. Under “What do you want to join to this layer?” select *Join data from another layer based on spatial location*
 - c. Under “1. Choose the layer to join to this layer” select your newly joined buffer layer
 - d. Under “2. You are joining:” select the first option *it fall inside*
 - e. Under “3. The result of the join will be saved...” give your new layer a name
 - f. Click on OK
4. Open the attribute table of your new layer and remove all fields except Count_ and Sum_valenc.
5. Click on the “Options” button at the bottom of the screen and select “Add Field...”.
6. Give your field the name “New_valenc” and click on OK.
7. Right click on “New_valenc” and select “Calculate Values...”
8. Double-click on “Sum_valenc” and click on OK. The values from the Sum_valenc field will have been copied over to the New_valenc field.
9. Click on the “Options” button and select “Select by Attributes”.
10. Set “Count” > 1.
11. Click on “Apply”.
12. Click on the “Show: Selected” button at the bottom of the screen.
13. Click on the “Options” button and select “Select by Attributes” (this window may still be open).
14. After “Method:” select *Select from current selection*.
15. Set “Sum_valenc” = 7.
16. Right click on “New_valenc” and select “Calculate Values...”.
17. Enter 3 in the box below “New_valenc =” and click on OK.
18. Repeat steps 9 through 17 using “Sum_valenc” = 12 in step 15.
19. Click on the “Show: All” button at the bottom of the screen.
20. Click on the “Options” button at the bottom of the screen and select “Clear Selection”.
21. Right click on the layer and select “Properties...”
22. Click the tab that says “Definition Query”.
23. Click the button that says “Query Builder”.
24. Under “Fields” double-click on the field “New_valenc”.
25. Click or type “=”. Under “Unique Values:” double-click on “3”.
26. Hit “OK”. The Query Builder window will close.
27. Hit “OK”. The Layer Properties window will close.
28. Now, only those intersections with a valence of 3 (3-way intersections) will be displayed. To display all intersections again, repeat steps 21-27 but remove the existing equation in the “Query Builder”.

Summarize 3-way Intersection Counts for multiple non-overlapping Sites:

1. If the site layer does not have unique IDs or names for each site, create them now.

2. Using a Spatial Join, assign the IDs from the sites to each intersection.
3. Open the attribute table of the intersection layer and select the field that contains the IDs.
4. Right-click on the field name and select Summarize.
5. Select or create an output file name and hit OK.
6. The output .dbf file will contain the counts of intersection nodes in each site.

Summarize 3-way Intersection Counts for multiple overlapping Sites:

1. If the site layer does not have unique IDs or names for each site, create them now.
2. Using your site polygon layer, select (highlight) the first study site.
3. Perform a "Select By Location".
4. Under "I want to:" choose *select features from*
5. Under "the following layers:" choose your intersection node layer
6. Under "that:" choose *have their center in*
7. Under "the features in this layer:" choose your site polygon layer
8. Make sure the box for "Use selected features" is checked
9. Hit "Apply"
10. Open the attribute table of the intersection node layer.
11. Text at the bottom of the window should show you how many intersections are selected. This is the number of intersections in the study site you currently have selected.
12. Record this number elsewhere (in a spreadsheet or Word file).
13. Repeat steps 2-6 for each study site.

Calculate 3-way Intersection Ratios for each Site

1. In a spreadsheet program such as Excel, open the file containing the summary of total intersection counts for each site created in protocol for **Intersections per Unit Area**.
2. Open the file containing the summary of 3-way intersection counts for each site.
3. Divide the numbers of 3-way intersections by the total numbers of intersections to get the 3-way intersection ratios for each site.

6.10 Connected Node Ratio

1. Basic Concept

This is a measure of the street pattern and is a ratio of the number of intersections (presumably valence 3 or more) divided by the number of intersections plus culs-de sac (with culs de sac valence 1) (Song and Knaap 2004, 214; Dill 2003, 3). A value close to one means that there are few culs-de-sac and therefore the street pattern is more highly connected.

Of course there could be a perfect grid with enormous blocks that were hard to get around and such a pattern would fare well on this measure so it is not a perfect indicator

2. Basic Formula

Connected Node Ratio = Number of street intersections divided by number of intersections plus culs-de-sac (Dill 2003, 3)

3. Detailed Formula

Connected Node Ratio = Number of street intersections (valence 3 or more) divided by the number of intersections plus culs-de-sac (valence 1) (Dill 2003, 3)

4. Comments and Explanations

A connected node ratio is the ratio of total intersections to intersections plus cul-de-sacs in a given study site. The maximum value of a connected node ratio is 1.00, indicated that there are

no cul-de-sacs within the study site. Dill (2003, 3) reports that ratios of 0.70 are preferred by those promoting highly connected street patterns.

For our analysis, we calculated connected node ratios with the intersections created between Interstates and on- and off-ramps removed. Given the coarse nature of the measure and the fact that the main distinction is between valence 1, valence 2 (omitted), and all other valences there is not much difference between using buffered or unbuffered intersections. However we calculated all three types--non-buffered, 10m buffer, and 15m buffer--to be consistent with our other intersection counts.

5. GIS Approach

From the intersection node layer, all cul-de-sacs were selected (valence of 1) and a new cul-de-sac layer created. For each study site, the number of cul-de-sacs and the number of total intersections were summarized and the ratio of intersections to intersections plus cul-de-sacs was calculated.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To follow this protocol you will need:

1. Site layer (polygon)
2. Intersection node layer (point)
3. *Total intersection counts* from protocol for calculating **Intersections per Unit Area** (these have been buffered)

The basic steps are:

- *Create Cul-de-sac Layer*
- *Summarize Cul-de-sac Counts for each Site*
- *Calculate Connected Node Ratios for each Site*

Create Cul-de-sac Layer:

1. Right click on your intersection layer and select "Properties".
 - a. Click the tab that says "Definition Query".
 - b. Click the button that says "Query Builder".
 - c. Under "Fields" double-click on "valence".
 - d. Click or type "=". Under "Unique Values:" double-click on "1".
 - e. Hit "OK". The Query Builder window will close.
 - f. Hit "OK". The Layer Properties window will close.
 - g. Now, only those intersections created by 1 road segment (cul-de-sacs) will be displayed.
2. Right click on your intersection layer and select "Data".
 - a. Select "Export Data..."
 - b. In the "Export Data" window:
 - c. Under "Export:" select **All features**
 - d. Check **Use the same Coordinate System as this layer's source data**
 - e. Create a name for your new cul-de-sac layer and hit **OK**
 - f. The new cul-de-sac layer will open separately.
3. Right click on your intersection layer and select "Properties".
 - a. Click on the tab that says "Definition Query".
 - b. Click on the button that says "Query Builder".
 - c. Your previous entry of "valence = 1" should still be shown. Change "= 1" to "> 2".
 - d. Hit "OK". The Query Builder window will close.
 - e. Hit "OK". The Layer Properties window will close.
 - f. Now, the intersection layer will once again only show intersections that are created by 3 or more road segments.

Summarize Cul-de-sac Counts for **multiple non-overlapping Sites**:

1. Using a Spatial Join, assign the IDs from the sites to each cul-de-sac point.
2. Open the attribute table of the cul-de-sac layer and select the field that contains the IDs.
3. Right-click on the field name and select Summarize.
4. Select or create an output file name and hit OK.
5. The output .dbf file will contain the total number of cul-de-sacs in each site.

Summarize Cul-de-sac Counts for **multiple overlapping Sites**:

1. Using your site polygon layer, select (highlight) the first study site.
2. Perform a "Select By Location".
 - a. Under "I want to:" choose **select features from**
 - b. Under "the following layers:" choose your cul-de-sac layer
 - c. Under "that:" choose **have their center in**
 - d. Under "the features in this layer:" choose your site polygon layer
 - e. Make sure the box for "Use selected features" is checked
 - f. Hit "Apply"
3. Open the attribute table of the cul-de-sac layer.
4. Text at the bottom of the window should show you the number of cul-de-sacs in the study site you currently have selected.
5. Record this number in the spreadsheet.
6. Repeat steps 1-5 for each site.

Calculate Connected Node Ratios for each Site:

1. In a spreadsheet program such as Excel, open the file containing the summary of *total intersection counts* for each site created in protocol for **Intersections per Unit Area**.
2. Open the file containing the counts of cul-de-sacs in each site.
3. Add the total intersection counts to the counts of cul-de-sacs in each site.
4. Divide the [number of intersections] by the [number of intersections plus cul-de-sacs] (from step 3) to get the connected node ratio for each site.

6.11 Median Perimeter of Block

1. Basic Concept

This is a measure of the road length per block, and captures the issue of curvilinear street patterns that might have smaller block areas but circuitous routes.

Future drafts of these protocols will examine how other researchers have used this measure (Song 2003).

2. Basic Formula

Median Census Block Perimeter = Median perimeter for census blocks with a centroid falling within the measurement geography.

3. Detailed Formula

Same as above.

4. Comments and Explanations

None.

5. GIS Approach

The GIS approach is to select all census blocks that have their centers in the measurement geography. Next, use XTools to calculate the perimeter of the identified census blocks. Perform a spatial intersect between the identified census blocks and the measurement geography. Import the Attribute Table of the resulting layer into Microsoft Access and analyze it using the PivotTable feature. Finally, copy the desired data out to an Excel spreadsheet and calculate the median perimeter.

6. GIS Steps

The following procedures were completed using ArcMap (ArcInfo) 8.3.

To complete this protocol you will need:

1. Site layer (polygon)
2. Census block layer (polygon)
3. **XTools** extension (available from the Downloads section of the ESRI website)
4. Microsoft Access
5. Microsoft Excel

The basic steps are:

- *Calculate Census Block Perimeters*
- *Create Centroid Layer*
- *Select Census Blocks*
- *Intersect Census Blocks and Study Sites*
- *Manipulate output in Access and export to Excel spreadsheet*
- *Calculate Median Census Block Perimeters for each Site*

Calculate Census Block Areas:

1. From the XTools menu, select "Table Operations" and then "Calculate Area, Perimeter, Length, Acres, and Hectares" (follow instructions included with the extension for XTools installation).
 - a. Under "Select layer to measure", select your new census block layer
 - b. Under "Desired output units", choose your units (depending on the census block size, try *Miles, Meters, or Feet*, for example)
 - c. Uncheck all boxes except Perimeter
 - d. Hit "OK"
2. A new field called "Perimeter" will be created in the attribute table of your new census block layer with the perimeter of each polygon calculated in the units you chose.

Create Centroid Layer:

1. From the XTools drop-down menu, select "Feature Conversions" and choose "Shapes to Centroids".
2. Under "Select the layer you wish to convert:" select your census block layer.
3. Give the layer a name and click on "OK".
4. The new layer will be added to your map document.

Select Census Blocks:

1. Add the census block centroid layer and the study site layer to your Map Document.
2. From the "Selection" drop-down menu, choose "Select by Location...".
3. Under "I want to:" choose "select features from".
4. Under "the following layers:" select your centroid layer.
5. Under "that" choose "have their center in".
6. Under "the features in this layer:" select your study site layer.
7. Hit "Apply". Now the centroids that fall inside your study sites will be selected.
8. From the "Selection" drop-down menu, choose "Select by Location...".
9. Under "I want to:" choose "select features from".
10. Under "the following layers:" select your census block centroid layer.

11. Under “that” choose “are completely within”.
12. Under “the features in this layer:” select your study site layer.
13. Hit “Apply”. Now the census blocks centroids that are inside the study sites will be selected.
14. Right click on your census block centroid layer and select “Data” and then “Export Data...”
15. After “Export:” choose selected features.
16. Choose “Use the same Coordinate System as this layer’s source data.
17. Give the new layer a name and click on OK.
18. When prompted, add the new layer to the Map Document.

Open the GeoProcessing Wizard.

1. Choose *Intersect two layers* and click *Next*
2. Select the exported subset of census block centroids from the previous step as the input layer
3. Select your study site layer as the overlay layer
4. Choose a name and location for the output layer
5. Click *Finish*
6. The new layer will be added to the Map Document

Import data into Microsoft Access

1. Open the Attribute Table of the layer created in the previous intersect step
2. Choose “Export” and select a location and name for the output DBF. NOTE: make the filename 8 characters or less so it can be imported into an Access database.
3. Open Microsoft Access and create a new blank database.
4. Go to File....Get External Data....Import
5. Find the DBF table you exported from ArcMap above and import it
6. Open the newly imported table
7. From the View menu, select PivotTable View
8. In the Field List window, select the name of the unique study site ID and drag it onto the large window where it says “Drop Column Fields Here”
9. From the Field List, drag the field containing the Perimeter onto the large window where it says “Drop Totals or Detail Fields Here”

Copy data into Microsoft Excel and calculate median

1. Open a new blank Microsoft Excel spreadsheet
2. In Access, click and drag the column headings to select them, and then do CTRL-C to copy them
3. Switch to Excel and do CTRL-V to paste them (NOTE: if you have more than 255 study site IDs, you will need to paste into multiple worksheet tabs, as Excel worksheets are limited to 255 columns)
4. Find the row beneath the last row to contain any values (each column will have a different number of values depending on how many census block centroids were found in each measurement geography)
5. Calculate the median of all the cells above containing perimeter values

The following variables are not proposed to be used in the study, so only a brief description and detailed formula are included.

6.12 Link-Node Ratio

This is the ratio of segments to nodes (intersections or the ends of culs-de-sac i.e. valences apart from 2). A perfect gird has a ratio of 2.5 (Dill 2003, 4). Given the character of the data in the Twin Cities Walking Study, this was very complicated to calculate.

Link-Node Ratio = Number of segments divided by the number of nodes in a measurement geography where a node is an intersection or an end of a cul-de-sac (i.e. valence 1 or 3 and above).

CHAPTER 7. OTHER BUILT ENVIRONMENT RELATED/SPATIAL VARIABLES

Initial outline by Ann Forsyth

Overview

The initial part of this manual focused on measuring the built environment, with a focus on residential areas. This chapter expands those measurements to the work environment (although most of the measures are virtually identical) and to other related topics such as crime, climate and air quality, and traffic.

This section will be expanded in subsequent versions.

Work Environments

Work environments have tended to be less studied than residential ones. This has been for theoretical reasons—everyone has a home environment but not all have a work one; the residential environment is an important environment in the parts of one's day with discretionary time. It is also for practical reasons—it is easy to get census data about where people reside but not where they work.

In the Twin Cities Walking Study we collected survey data including work addresses. However, it should be noted that not everyone goes to (paid) work. Many people are retired, homemakers, or unemployed. Others are at colleges or universities that they do not class as work. Still others work part time or in multiple locations. Overall, studying the work environment is a complex matter.

Subsequent versions of this manual will outline the specific measurements we make of the work environment.

Crime

Crime affects where, when, and how much people walk. However, there are good theoretical reasons to consider that perceptions of crime are more important than the reality of crime. The Twin Cities Walking Study asked participants to respond to a number of statements about crime, taken from the Neighborhood Quality of Life Survey (NQLS):

1. My neighborhood streets are well lit at night.
2. Walkers and bikers on the streets in my neighborhood can be easily seen by people in their homes.
3. I see and speak to other people when I am walking in my neighborhood.
4. There is a high crime rate in my neighborhood.
5. The crime rate in my neighborhood makes it unsafe to go on walks during the day.
6. The crime rate in my neighborhood makes it unsafe to go on walks at night.

As local crime statistics were very unevenly available in the study area, we used these perception variables.

Climate and Air Quality

Climate and air quality both vary with a region and have some differences within a region. The Twin Cities Walking Study only measured individuals in the warmer months of April to November.

Climate data are available from central sources and we will use these data in our analyses.

Air quality is very complex to measure and the variation is not very different in the Twin Cities.

Traffic

Traffic affects where, when, and how much people walk. The Twin Cities Walking Study asked a number of questions about perceptions of traffic:

1. There is so much traffic along the street I live on that it makes it difficult or unpleasant to walk in my neighborhood.
2. There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood.
3. The speed of traffic on the street I live on is usually slow (30 mph or less).
4. The speed of traffic on most nearby streets is usually slow (30 mph or less).
5. Most drivers exceed the posted speed limits while driving in my neighborhood.
6. There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood.
7. The crosswalks in my neighborhood help walkers feel safe crossing busy streets.
8. When walking in my neighborhood there are a lot of exhaust fumes (such as from cars, buses).

While significant data are available for traffic, each has a number of problems of coverage or relevance. We investigated the following potential measures:

- Traffic counts. These were only available for major roads which were spaced quite widely. Many of the smaller measurement geographies did not overlap with any of these roads.
- Posted traffic speed. This was available for all roads in the study area, however, there was a huge range of roads with a posted speed of 30 miles per hour including some of the most and least busy. As a measurement it did not seem useful.
- Functional classification. This was available for all roads in the study area. It more accurately reflects the “busy-ness” of major streets.

7.1 Proportion of High Functional Classifications

1. Basic Concept

Functional classifications of roads divides roads into a hierarchy. In the Metropolitan Council’s dataset prepared by The Lawrence Group the classifications are modified versions of the US Census Bureau’s classification in TIGER Line Files including many subclasses of the following road types (U.S. Census 2005, 3-28).

- Primary Highway With Limited Access—mostly interstates
- Primary Road Without Limited Access—mostly US and state highways
- Secondary and Connecting Road—mostly state and some county highways
- Local, Neighborhood, and Rural Road
- Vehicular Trails

This measure assesses the ratio of higher road classes to local and neighborhood roads. It would also be possible to examine the density of higher classifications.

2. Basic Formula

Proportion of High Functional Classifications = Proportion of primary, secondary, and connecting roads to all roads.

3. Detailed Formula

Proportion of High Functional Classifications = Proportion of primary, secondary, and connecting roads to all roads excluding vehicular trails, and gated roads.

4. Comments and Explanations

We currently plan to convert the following local road classifications to classifications of high functional classes:

A10	213	Primary highway with limited access
A20	122	Primary road without limited access
A25	388	Primary road without limited access
		Primary road without limited access, US highways, separated
A30	2144	Secondary and connecting road
A63	348	Road with special characteristics
		Access ramp, the portion of a road that forms a cloverleaf or limited access interchange
A64	34	Road with special characteristics
		Service drive, the road or portion of a road that provides access to businesses, facilities, and rest areas along a limited-access highway

Other roads:

A40	13651	Local, neighborhood, and rural road
A71	47	Road as other thoroughfare
		Walkway or trail for pedestrians, usually unnamed
A73	3	Road as other thoroughfare
		Alley, road for service vehicles, usually unnamed, located at the rear of buildings and property

Excluded:

A66	114	Road with special characteristics
		Gated barrier to travel
A98	5	* not listed *
		This is the University's bus transitway which has bike but not pedestrian access.

5. GIS Approach

[To come]

6. GIS Steps

[To come.]

CHAPTER 8. DATA STORAGE AND SHARING

By Jason Zimmerman, Joel Koepp, and Ann Forsyth

Note: This was new in version 2.2.

Steps/problems with obtaining our data

MetroGIS data server

In the Twin Cities, MetroGIS – an organization that coordinates data sharing among a number of local governments – maintains a data server that allows access to a number of metro-wide data sets free of charge (municipal boundaries, water bodies, and land use data sets are among those provided). These data have been aligned and cleaned as much as possible to provide consistency across municipalities. Much of our base data was obtained from the DataFinder web site (<http://www.datafinder.org>).

User license agreements (Regional parcels)

In order to access the regional parcel data set (an item on the MetroGIS DataFinder), it was necessary to enter a separate license agreement. At the time the data was requested, this involved two license agreements – one that covered six of the seven metro counties and another that covered the seventh. This second agreement proved to be a much harder agreement to reach, and involved exchanges of agreement language between University attorneys and attorneys for the county. By the time this hurdle was completed, however, a new wrinkle emerged. At the end of the approaching calendar year the contract for data sharing between MetroGIS and the seven counties expired and was in the process of being renegotiated. This ended up taking many months to finalize, greatly extending the time before we were able to finally obtain access to the regional parcel data set.

Luckily, while all of this was going on, we were able to rely on our previous relationships with two of the counties to use their parcel data free of charge. We did, however, need to purchase small areas of parcel data from two additional counties where the largest buffers of our study area spilled over across county boundaries.

I-35W Coalition agreement/Access to Ramsey County/St. Paul data

A memorandum of understanding with the I-35W Coalition (a coalition of seven cities within two counties) allowed us to access a large amount of high-quality data for free (a significant lump sum was paid to the Coalition to cover time for the GIS Coordinator to assist with data problems, but there was no charge to access the data itself).

This arrangement had additional benefits when we began to look for data outside the boundaries of the Coalition. The Coalition's membership in the Ramsey County Users Group allowed us to access data for the whole of Ramsey County – not just for the Ramsey portion of the Coalition cities. However, it would have been possible just to join the Ramsey County Users Group and in the end this would likely have been less expensive. This highlights some of the challenges in deciding which of many complex arrangements one must decide on in accessing data.

Data for the City of St. Paul (which lies within Ramsey County but is not a member of the Coalition) was also easier to obtain because of this relationship although we spent some time in negotiations.

Problems that arose in obtaining data from the City of St. Paul were mostly due to the dispersed nature of the data. Data for street trees needed to be obtained directly from the Parks Department. Data for sidewalks and street lights needed to be obtained from Public Works. Difficulty in coordinating messages, confirming approvals, and exchanging data was the biggest obstacle in obtaining information from St. Paul.

Storing/Sharing data

Central server

GIS data, documentation, and tracking spreadsheets are all stored on a single file server. With a small project team issues of file locking are infrequent and easily handled. All data are backed up to a separate dedicated server on an incremental basis nightly, with a fresh full backup occurring once a week.

Working files kept locally

Many measurements require several large processing operations on data before it is ready for final calculations. To aid the efficiency of computationally intensive GIS tasks, working data files are kept on local machines rather than on a network. For example, in the process of calculating median block size for 1600m straight line buffers of the 715 participants with good addresses, one of the files generated contained over 2.5 million features and consumed nearly a gigabyte of disk space. This intermediate file then had to be broken into smaller pieces so ArcGIS would be able to process them. Even working off local hard drives these processes are intensive, and it would take much longer even on the fastest of local networks if the files were saved on a server due to network latency.

“Final” files on server

Important base data and final versions of modified files are stored on a central file server for access by multiple users. Rather than storing shapefiles and dealing with the resulting clutter of having dozens of layers in separate folders, we used the geodatabase storage format, introduced to ArcGIS in version 8. The geodatabase can store multiple layers and tables together in one large file (which is actually a modified Microsoft Access database). We created several geodatabases named by topic, e.g. Street Features, Density, Buffers, etc. Among the benefits of using the geodatabase format is that line and polygon features automatically have their length and area fields recalculated when modified. It is important to note that the file size of a geodatabase cannot exceed 2 GB, so when working with very large datasets, multiple geodatabases may be needed.

Issues with multiple users

While the geodatabase is convenient for data storage, one limitation is that the basic ArcGIS or ArcINFO install does not support some of the advanced features of the format. With an installation of the ESRI product ArcSDE (designed for file servers that share and manage GIS data), it is possible for multiple users to edit a geodatabase layer simultaneously. The other capability afforded by ArcSDE is versioning, which would help keep track of changes made to a layer throughout the stages of geoprocessing performed on base data.

Our college did not have a license for ArcSDE.

Tracking changes/updates

Work was tracked in a number of ways:

Shapefile tracking sheet

This Excel spreadsheet is to keep track of which layers get put in the geodatabases on the central server. There are fields for the name of the layer, the geodatabase in which it is found, the date created, the date last modified, the features in the layer, and miscellaneous notes. It is updated each time a layer is added or replaced. This is a way of avoiding having to purchase ArcSDE.

Decision logs

Logs are kept by both GIS Research Fellows throughout the study. These documents, updated at least weekly, record key decisions that were made regarding GIS, conversations that were held, and tasks that were performed. These logs carry out two functions: they allow the Principal Investigator to be kept in the loop and they act as a record of GIS-related information over time that can be reviewed when questions arise at a later date.

Updating/tracking measurement results

A master measurement spreadsheet with tabs for each variable stores variables.

Checklist

A checklist of variables was maintained, with numbering from Protocols, required geographies in columns, and filled in with name and date when completed. A version of this checklist is in Appendix 1D.

Other issues

Projections

The standard coordinate system for MetroGIS datasets is Universal Transverse Mercator (UTM) North American Datum 1983 (NAD83), Zone 15. Any working or final files created from MetroGIS data was kept in the same coordinates. Some data layers which came from individual cities or from Ramsey County—such as street lights, street trees, and sidewalks—came in the Ramsey-Hennepin coordinate system. Because ArcGIS has the capability to correctly display data from multiple projections in the same view, these layers remained in Ramsey-Hennepin coordinates.

Much of the street feature data was hand digitized using high resolution color aerial photos of Ramsey County. Imagery cannot have coordinate system information attached to it like shapefiles or geodatabase feature classes, so the data view must be set to the known coordinates of the imagery. As a result, when the hand digitized features were saved from graphics to a shapefile, they were saved in Ramsey-Hennepin coordinates.

Converting Measures: Blocks and Minutes to Meters

A number of survey measures asked participants to estimate distances in blocks. We investigated how long to make the block. Susan Liss from the National Household Transportation Survey indicated 1/9 of a mile as appropriate. However, other experts including Kevin Krizek used 1/10 of a mile as a rule of thumb. We estimated the median block length in the area as closer to 1/10 of a mile or 160 meters and used that measure.

APPENDICES

Note: If there is a specific author for each section he, she, or it is named at the beginning of the section. Appendices 1D and 1F are new in version 2.3.

Appendix 1A: I-35W Corridor Coalition Land Use Metadata

North Metro I-35W Corridor Coalition
Land Use Designations
(Definitions Adopted as of 1/15/98)
(Updated 1/19/99)

Following are the Land Use designations, definitions, notes, and samples developed and adopted by the North Metro I-35W Corridor Coalition.

General Notes:

¹Land use designations, unless otherwise specified, refer to the predominant identifiable land use on a parcel or portion thereof.

²The sample uses listed after each category indicate the types of land uses that fit into each land use category assuming they meet the criteria outlined in the definition. Some land uses may fit into more than one category (for example, gas stations may be categorized as Neighborhood Commercial, Community Commercial, or Highway/Convenience Commercial depending on their size, location, etc.). Sample land uses are simply intended to give the user an idea of the typical land uses within each category. They are not intended to be the only criteria for categorizing land use.

³The land use categories, definitions, and samples outlined below were developed to serve areas ranging from first-ring suburbs to outer-ring suburbs. These categories and definitions may not be sufficient for rural or core urban areas.

Agricultural (AG)

Definition:

Land used for agricultural purposes, including farming, dairying, pasturage, horticulture, floriculture, viticulture, and animal and poultry husbandry and accessory uses; provided that such accessory uses shall be incidental to the agricultural activities.*

*Note:

¹Agricultural properties with a residential density of less than one unit per twenty acres may be considered Residential if a majority of the land is not used for agricultural production (Hobby Farms).

²Some traditional Agricultural uses may not be considered Agricultural if they conform more closely with definitions and samples for commercial or industrial land uses.

Samples:

Agricultural land uses would typically include any of the following that meet the previously defined criteria:

Cash Grain or General Farm

Other Agricultural Use

Sod Farms

Residential (RES)

*Note: This section contains a general definition of residential land use followed by several subset definitions. It is intended that land uses falling within a subset definition meet the criteria outlined in the general definitions plus the additional criteria outlined in the subset definition.

General Definition:

Land containing a building or portion thereof used exclusively for residential purposes, including one-family, two-family, and multiple-family dwellings, but not including hotels, motels, and boarding and lodging houses, nursing homes, or elderly care facilities; or open space within or related to a residential development, not in individually owned lots or dedicated for public use, but which is designed and intended for the common use or enjoyment of the residents of the development.*

*Note: Residential properties with a density of less than one unit per twenty acres may be designated as Agricultural if a majority of the land is used for agricultural production (Hobby Farms).

i.) Rural (R)

Definition:

Land meeting the general definition of residential and which is outside the MUSA boundary containing a residential building with not more than one dwelling unit entirely surrounded by open space on the same lot.

ii.) Single-Family, Detached (SFD)

Definition:

Land meeting the general definition of residential and containing a residential building with not more than one dwelling unit entirely surrounded by open space on the same lot.

Single Family Dwelling, Platted Lot

Mobile Home on Real Estate

iii.) Single-Family, Attached (SFA)

Definition:

Land meeting the general definition of residential and containing one or more buildings containing two or more dwelling units, each of which has primary ground floor access to the outside and which are attached to each other by party walls without openings.

Two Family Dwelling, Platted Lot

Conversion

Three Family Dwelling, Platted Lot

Double Dwelling

Townhome-Inner

Townhome-Outer

Townhome Non-Tax Outlot

iv.) Multifamily (MF)

Definition:

Land meeting the general definition of residential and containing one or more buildings containing three or more dwelling units, one or more of which does not have primary ground floor access to the outside and which are attached to each other by party walls without openings.

- Apartments, 1-9 Rental Units
- Apartments, 10-19 Rental Units
- Apartments, 20-49 Rental Units
- Apartments, 50 or More Units
- Apartment Misc. Improvements
- Condominium
- Condominium Non-Tax Lot

v.) Manufactured Housing Park (MHP)

Definition:

Land meeting the general definition of residential and under single ownership that has been planned and improved for the placement of manufactured housing for dwelling purposes.

- Trailer or Mobile Home Park

Commercial/Retail

i.) Neighborhood (NC)

Definition:

Land use primarily engaged in the provision of goods or services with a primary service radius of 1 to 1.5 miles. Neighborhood Commercial/Retail Land Uses would typically be located in a predominantly residential area and have a Gross Leasable Area (GLA) of approximately 25,000 square feet or less.

Samples:

Neighborhood Commercial/Retail land uses would typically include any of the following that meet the previously defined criteria:

- Small (Under 10,000 sq. ft.) Detached Retail
- Neighborhood Shopping Centers
- Restaurant, Cafeteria, and/or Bar
- Dry Cleaning Plants and Laundries
- Automotive Service Station
- Barber/Beauty Shops

ii.) Community (CC)

Definition:

Land use principally engaged in the provision of goods or services with a primary service radius of 3 to 5 miles. Community Commercial/Retail Land Uses would typically be located in a small commercial/retail center with a Gross Leasable Area (GLA) of approximately 50,000 to 150,000 square feet.

Samples:

Community Commercial/Retail land uses would typically include any of the following that meet the previously defined criteria:

- Supermarkets
- Discount Stores & Jr. Dept. Stores
- Community Shopping Center
- Other Retail Structures
- Funeral Homes
- Full Service Banks
- Savings & Loans
- Auto Car Sales and Services
- Bowling Alleys
- Restaurant, Cafeteria, and/or Bar
- Automotive Service Station
- Other Commercial Structures
- Car Wash
- Day Care Centers

iii.) Regional (RC)

Definition:

Land use principally engaged in the provision of goods or services with a primary service radius of 10 or more miles. Regional Commercial/Retail Land Uses would typically be located in or near a large commercial/retail center with a Gross Leasable Area (GLA) of approximately 350,000 square feet or more.

Samples:

Regional Commercial/Retail land uses would typically include any of the following that meet the previously defined criteria:

- Nurseries
- Full Line Department Stores
- Regional Shopping Center
- Parking Garage Structure & Lots
- Parking Ramps
- Theaters
- Drive-in Theaters
- Lodge Halls and Amusement Parks
- Marine Service Facilities
- Sport/Public Assembly Facility

iv.) Highway/Convenience (HC)

Definition:

Land use principally engaged in the provision of goods or services that primarily services customers attracted from a nearby major transportation arterial.

Samples:

Highway/Convenience Commercial/Retail land uses would typically include any of the following that meet the previously defined criteria:

- Motels and Tourist Cabins
- Hotels
- Drive-in Rest/Food Service Facility
- Gas Station
- Automotive Service Station

Office (OFC)

Definition:

Land use predominantly involved in administrative, professional, or clerical services.

Samples:

Office land uses would typically include any of the following that meet the previously defined criteria:

- Office Building, 1-2 Stories
- Office Building, 3 or More Stories Walkup
- Office Building, 3 or More Stories Elevator
- Veterinary Clinic
- Medical Clinics and Offices

Mixed Use (MU)

Definition:

Land containing a building with significant amounts of residential uses in combination with commercial and/or office uses.*

* Notes:

¹Land is identified as Mixed Use only if it contains buildings with stacked or multiple uses in which there is a significant amount of residential use. Properties with only a small amount of residential use (such as caretakers quarters, etc.) are assigned the predominant land use.

Samples:

Mixed Use land would typically include any of the following that meet the previously defined criteria:

- Residential apartments over commercial or office uses

Industrial

i.) Light (LI)

Definition:

Land used primarily in the manufacture, processing, fabrication, assembly, packaging, incidental storage, sales, and distribution of predominantly previously prepared materials, finished products or parts. Light Industrial land uses would typically have all processing within buildings, require limited exterior storage, generate limited amounts of truck or rail traffic, and be free of hazardous or objectionable elements such as noise, odor, dust smoke, glare, or other pollutants.

Samples:

Light Industrial land uses would typically include any of the following that meet the previously defined criteria:

- Greenhouses, Vegetables & Floriculture
- Food & Drink Process Plants and Storage
- Manufacturing & Assembly, Light
- Small Shops (Machine, Tool & Die, etc.)
- Other Industrial Structures

Flex Industrial Center
Mini Warehouse
Research and Development Facility

ii.) Heavy (HI)

Definition:

Land used primarily in the manufacture and/or processing of products from large bulky, predominantly raw, extracted, or hazardous materials; or use engaged in the storage of flammable, explosive, or other materials that may pose a threat to public health or safety. Heavy Industrial land uses may require exterior storage of large equipment or material, be engaged in outside processing or assembly, generate significant amounts of truck and/or rail traffic, or emit limited amounts of objectionable elements such as noise, odor, dust, smoke, glare, or other pollutants.

Samples:

Heavy Industrial land uses would typically include any of the following that meet the previously defined criteria:

- Foundries & Heavy Manufacturing Plants
- Grain Elevators
- Commercial Warehouses
- Commercial Truck Terminals

Institutional (IN)

Definition:

Land used for primarily religious, governmental, educational, social or health care facilities excluding clinics.

* Notes:

¹ Symbols may be used to differentiate between different types of institutional uses.

Samples:

Institutional land uses would typically include any of the following that meet the previously defined criteria:

- Nursing Homes & Private Hospitals
- Exempt Property Owned by USA
- Exempt Property Owned by State of MN
- Exempt Property Owned by Counties
- Firestations
- Exempt Property Owned by Municipalities
- Sport/Public Assembly Facility
- Library
- Exempt Property Owned by Board of Education
- Exempt Property Owned by Private Schools
- Charitable Exempt Hospital/Nursing Home
- Welfare/Charitable Facility
- Churches, Etc. Public Worship – Private
- Graveyards Monuments, Cemeteries

Sport/Recreation

i) Indoor (SRI)

Definition:

Land containing a building(s) developed, used, and maintained primarily for recreational activities.

Samples:

Indoor Sport/Recreation land uses would typically include any of the following that meet the previously defined criteria:

- Ice/Hockey Arenas
- Indoor Soccer Fields
- Domed recreational facilities
- Large scale health/fitness clubs
- Indoor swimming pools
- Sport/public Assembly Facility

ii) Outdoor (SRO)

Definition:

Land used primarily for public recreation activities improved with playing fields, playground or exercise equipment and associated structures.

Samples:

Outdoor Sport/Recreation land uses would typically include any of the following that meet the previously defined criteria:

- Baseball/Softball fields/stadiums
- Soccer/football fields/stadiums
- Golf Courses
- Golf Driving Ranges
- Mini Golf Courses
- Playground equipment

Open Space

i.) Passive (OSP)

Definition:

Land used and maintained for resource protection, amenity, or buffer, which supports unorganized public recreational activities and which may contain trails, picnic areas, public fishing/boating docks, etc.

Samples:

Passive Open Space uses would typically include any of the following that meet the previously defined criteria:

- Exempt Cultural & Nature Exhibits

ii.) Natural (OSN)

Definition:

Predominantly undeveloped or unaltered land preserved in its natural state for environmental or aesthetic purposes.

Samples:

Natural Open Space uses would typically include any of the following that meet the previously defined criteria:

Wetlands

Timber or Forest Lands

Nature Preserves

Utility (UTL)

Definition:

An area or strip of land, either public or private, occupied by a power plant or substation, electric transmission line, oil or gas pipeline, water tower, municipal well, reservoir, pumping station, water treatment facility, communications tower, or similar use.

Samples:

Utility uses would typically include any of the following that meet the previously defined criteria:

Comm Ld & Impro Own by Pub Uti Th Rail

Transportation

i.) Vehicular/Pedestrian Right-of-Way (ROW)

Definition:

An area or strip of land, either public or private, on which an irrevocable right-of-passage has been recorded for the use of vehicles or pedestrians or both.

Samples:

Transportation Right-of-Way uses would typically include any of the following that meet the previously defined criteria:

Skyways

Street Right-of-Way

Sidewalks/Paths/Trails

ii.) Railway (RLW)

Definition:

An area or strip of land occupied or intended to be occupied by a railroad or other similar use.

Samples:

Railway uses would typically include any of the following that meet the previously defined criteria:

Railroad Real Property Used in Operation

Railroad Real Property Not Used in
Operation

iii.) Airport (AP)

Definition:

Land Used for the operation of aircraft and associated accessory uses; provided accessory uses are incidental to the airport activity.

Samples:

Airport land uses would typically include any of the following that meet the previously defined criteria:

Landing strips/runways

Airplane hangers
Helipads
Air-traffic control facilities
Boarding terminals

Vacant (VAC)

Definition:

Land not currently used for any defined purpose that may or may not contain buildings or other structures.

Samples:

Vacant land uses would typically include any of the following that meet the previously defined criteria:

Agricultural, Vacant Land
Industrial, Vacant Land
Commercial, Vacant Land
Apartment, Vacant Land
Residential, Vacant Land, Lot
Vacant Land
Exempt HRA Vacant Land

Open Water (WAT)

Definition:

Permanently flooded open water not including wetlands, or periodically flooded areas.

Samples:

Open Water would typically include any of the following that meet the previously defined criteria:

Lakes
Rivers
Streams (not intermittent)
Ponds (permanently flooded)

Appendix 1B: Excensus Metadata

Twin Cities Walking Study - Employment Summary
Prepared by Excensus LLC

Overview of Methodology for St. Paul Area

- I. Obtained database of current employers within study area from Dun & Bradstreet (DNB)
- II. Verified coverage of DNB dataset against requested geographies
- III. Cleaned and standardized DNB employer records
- IV. Geocoded DNB employer records and resolved unmatched records
- V. Manually reviewed points (with 5 or more employees) placed just outside of context area boundaries to determine whether they should be included
- VI. Merged DNB data with previous employment data from I35W Corridor project
- VII. At this stage there were two products. One assigned employer points to 100-meter grid cells, taking into account overlapping context areas. The other gave the “raw” data which was in fact what we used.
- VIII. Summarized employment counts in each cell, including the requested retail breakouts

Structure of Employment Summary Shapefile (Employment_Summary_100m.shp)

Field Name	Description
Shape	Type of shapefile
ID	100-meter grid identifier
Context	Area identifier
Group	Allows context areas to be grouped into non-overlapping groups
Type	Indicates whether grid cell is in a context or a focus area
Num_Empl	Total number of employees within grid cell
Num_Retail	Number of employees in retail businesses (SIC 52xx – 59xx)
Num_GenMer	Number of employees in general merchandise businesses (SIC 53xx)
Num_Food	Number of employees in food stores (SIC 54xx)
Num_EatDri	Number of employees in eating & drinking establishments (SIC 58xx)
Num_MisRe	Number of employees in miscellaneous retail businesses (SIC 59xx)

Appendix 1C: GIS Digitizing and Fieldwork for Street Trees, Street Lamps, and Sidewalks

By Joel Koepp

This is an account of how the research team created street tree, street lamp, and parcel data layers for the 1.0*1.0 mile / 1609*1609 meter context areas. Digitizing was done by two undergraduate research assistants—Jorge Salcedo and Ian Kaminski-Couglin. Data conversion was done by research fellows Joel Koepp and Jason Zimmerman. Joel Koepp did all field checking of data. Ann Forsyth did a small amount of work to figure out a method for dense stands of trees that had continuous canopies in the digital orthophotos.

Digitizing

The color high-resolution digital orthophotos served as the basis for the digitizing of street features. The study areas were divided into groups so the undergraduate research assistants could be working in parallel to complete the digitizing.

For places where no sidewalk data could be obtained from the cities, sidewalks identifiable in the orthophotos were digitized using the basic drawing tools in ArcMap. A polyline was drawn down the middle of the sidewalk for each sidewalk segment, starting and ending where the sidewalk met the road. In the cases where a sidewalk meets a driveway and continues on the other side, the line was drawn so that it continued across the driveway rather than being broken into 2 separate lines. When all the sidewalks were digitized and checked, they were converted into a GIS shapefile using the XTools extension, which can convert graphics into spatial data with attributes.

Street lights were digitized by inspecting the orthophotos and using the drawing tools to place a dot at the base of each light pole. The majority of street lights were identifiable due to the unique shadows created on the ground. Along major arterials, particularly in the suburbs, most lights consist of a pole and an attached arm that hangs out over the road. The shadow it created was very distinctive, so it was not difficult to locate the base of the pole using this shadow. In the City of Saint Paul, residential streets use one or two styles of light fixtures in a consistent fashion throughout entire neighborhoods. They are located at regular intervals and so were relatively easy to identify and digitize. In places where a street light could not be distinguished from a utility pole or tree, the point was digitized and left to be resolved in field checking.

Trees were digitized in much the same way as street lights. The drawing tools were used to place a point on each tree for all trees up to the front face of a house, and for a similar distance away from the street in non-residential areas. In places where the density of trees was too high to distinguish individual trees with enough accuracy, the cluster of trees was drawn using a polygon. These polygons were to be field checked later to assign a tree density and arrive at a count.

Field Checking

The laptop was loaded up with the GIS software (both ArcMap and ArcView) and all the relevant data: focus and context areas, streets, parcels, and the digitized sidewalks, street trees, and street lights. The GPS receiver was also taken.

In general terms, the goal of field checking was to verify the existence of the features we had digitized in the office. Where necessary, features not found or not identifiable on the

orthophotos would be added, and features mistakenly digitized (e.g., telephone pole mistaken for light pole) would be removed. In addition, fieldwork also included taking photos of tree stands where the tree density on the orthophotos was too high to distinguish individual trees.

The first context area was done in conjunction with two research assistants doing the separate urban design inventory. For this area checking used paper maps and any changes were marked directly on them. Back at the office changes were made in GIS based on the map notations. This checking also involved walking the streets, doing a small area on foot, then driving the car a short distance to a new area, getting out and walking again.

After one day it was clear that walking was not a viable long-term option for completing field work in the time frame the research team had laid out for it. It also turned out that the paper maps strategy was cumbersome, because this involved making edits on the paper and then having to repeat them in the GIS to change the actual data. From then on, edits were made directly to the data in GIS, adding and deleting features as necessary.

To check data on a given street, the field checker drove slowly down the street and parked along the side two or three times to check what he was looking at against the data on the screen. In a few places there were streets that were either too busy to park on or where parking was not allowed. For those situations he found a nearby place to park and walked with the laptop.

The first feature he would check was sidewalks, as it was the feature that required the least amount of editing. Typically he could tell immediately by looking down the street if there were sidewalks on one or both sides, or none at all. If a sidewalk was there that he didn't have data for, he drew it in for the whole length of street by default. One or two times he would again edit that sidewalk if it turned out not to extend to the end of the street. For streetlights, his normal procedure was to count the number of lights on each side of the street and check against the GIS. In suburban areas, lights were usually found only on one side of a street. On most streets in Saint Paul, the pattern is to have evenly spaced streetlights on alternating sides of the street, and then usually two lights on opposite corners at an intersection. In places where his GIS data clearly indicated that he was missing a street light, he would locate it on the street and make a note of how many houses away from the corner or end of the street it was. That information allowed me to use the parcel data in the GIS as a reference for adding in the point. For trees, he would check the number of trees in a front yard against what was on the screen, and in places where the GIS data was missing a significant number of trees he digitized them in. Obviously without using the GPS the tree locations were not precise, but for the purposes of the eventual variable the number of trees is going to be crucial.

For keeping track of progress, the field checker checked off street segments on a paper map, as this was quite a bit more efficient than doing the equivalent within GIS.

After every day of field work, he compressed the GIS data into a zipfile and transferred it to his computer at work via FTP for backup purposes.

The field checker took all the tree photos with a digital camera. He began by erasing all data on the camera memory card and all waypoints on the GPS. When he came to a stand of trees that needed to be photographed (as indicated by the "dense tree area" polygons that Ian and he digitized), he stopped the car, took a picture, and then immediately recorded his position with a GPS waypoint. This way, each photo had a corresponding waypoint. At the end he had the same number of photos and waypoints, and both were in the order in which he recorded them so they could be easily associated with each other. he used the Garmin software and an

ArcView extension called AVGarmin to retrieve the waypoints from the GPS and convert them into a shapefile. Finally he created an ArcMap project with all the waypoints and linked in the tree images.

Appendix 1D: Matrix of Measures by Measurement Geography Used in Twin Cities Walking Study

Measurement	STRAIGHT				NETWORK					Dist. to Near	P a r c e l
	200	400	800	1600	200 a	200 b	400	800	1600	grid	
3.1 Raw Population per Unit Land Area											
3.15 Net Land Area											
3.2 Population per Unit Land Area (without water)											
3.3. Population per Developed Land Area											
3.4 Residential Population in Residential Parcels (Residential Density)											
3.5 Population plus Employment per Unit Land Area (excluding water)											
3.6 Employment per Unit Land Area											
3.7 Housing Units per Unit Land Area (gross, census data)											
3.8 Lot Coverage											
4.1 Sidewalk Length per Unit Area											
4.2 Sidewalk Length Divided by Road Length											
4.3 Sidewalks Length divided by Major road Length											
4.4 Street Lights per Length of Road											
4.5 Street Trees (trees within an X foot/ meter buffer) per Length of Road											
4.6 Percent of Street Segments with Marked Pedestrian Crossings at One or Both Ends											

4.7 Percent of Street Segments with Visible Litter, Graffiti, or Dumpsters												
4.8 Percent of Street Segments with Traffic Calming, Broadly Defined												
4.9 Other fieldwork based measurements of neighborhood identification, street crossing, street characteristics, views, land uses, barriers, sidewalks, bicycle lanes, mid block crossing, steepness, sidewalk amenities, street trees, buildings, windows, other features of buildings, garages, parking, driveways, maintenance, lighting, freeways, traffic features, architecture / design.												
4.10 Distance to nearest Bus Stop												
4.11 Bus Stop Density												
5.1 Percentage of Total Parcel Area in Major Land Uses (seven land uses in this case)												
5.2 Percentage of Land Area in Night Time Uses												
5.3 Percentage of Land Area in Social Uses												
5.4 Percentage of Land Area in Retail Uses												
5.5. Percentage of Land Area in Industrial and Auto-Oriented Uses												
5.6 Dissimilarity Index, Formula 1												
5.7 Proportion of Dissimilar Land Uses Among Grid Cells in an Area (Formula 1)												
5.8 Dissimilarity Index, Formula 2												
5.9 Entropy Index												
5.10 HH Index												
5.11 Retail Employment per Acre												
5.12 Density of Employees in Major Retail Subcategories: General Merchandise (old SIC 53xx); Food Stores (54xx); Eating and Drinking Places (58xx); Miscellaneous Retail (59xx).												

5.13 Distance to nearest gen merchansise												
Food stores												
Eating and drinking												
Misc retail												
5.14 Distance to nearest facility (for comparison with NQLS)												
5.15 Gravity measure with competition												
UNC Measures e.g. Entropy index; HHI Index												
6.1 Average Census Block Area												
6.2 Median Census Block Area												
6.3 Ratio of Area within X Street Distance to Area within X Distance Radius												
6.4 Number of Access Points												
6.5 Road Length per Unit Area												
6.6 Intersections per Unit Area												
6.7 Ratio of 4-Way Intersections to All Intersections												
6.8 4-way Intersections per Unit Land Area												
6.9 Ratio of 3-way Intersections to All Intersections												
6.10 Connected Node Ratio												
6.11 Median Perimeter of Block												

Appendix 1E: Other Data and Measurement Issues

By Joel Koepp and Jason Zimmerman with Ann Forsyth

1. Projections

For these measurements we used the UTM NAD83 Zone 15 coordinate system, which uses the meter as its fundamental unit. This is the coordinate system used by the Metropolitan Council for all of its endorsed regional datasets. Some datasets received from counties were used in their native coordinate system, such as the Ramsey County parcels, which come in the Ramsey-Hennepin coordinate system (this uses the foot as its fundamental unit). Datasets digitized from the Ramsey County orthophotos (sidewalks, street trees, street lights) were created in Ramsey-Hennepin coordinates originally but then converted to UTM coordinates later.

2. Transformation of Raw Data to Final Form

Water

Sources: Ramsey County water layer, Met Council hydro layer (from 2000 land use data)

Steps:

1. Merge Ramsey County and Met Council layers to get most complete coverage
2. Along Rice Creek in Anoka County, make manual corrections due to poor digitizing and poor alignment of Ramsey and Anoka parcels

Parcels

Sources: Ramsey County, Anoka County, Hennepin County, Dakota County (or Met Council Regional Parcel Dataset)

Steps:

1. Clip and merge parcels from various counties (or clip from Met Council data)
 - a. Remove Dakota right of way (included as a polygon)
2. Union water layer
3. Correct manually some parcels due to updates in parcel attribute information (see below)
4. Create manually some new parcels along Mississippi (see below)
5. Correct old plat of right of way in Dakota County (along river)
6. Add manually a parcel in Mounds View that was left out
7. Manually adjust alignment of some parcels in St. Paul
8. Create road right of way layer from space left between parcels

Land Use

Sources: I-35W land use data (polygon matched to parcel lines), Ramsey County land use data (parcel), Ramsey County on-line property information search, Ramsey County on-line maps (parks), Metropolitan Council land use data (polygons), City of St. Paul park data (parcel data), field-checked land use data in Anoka, Dakota, and Hennepin Counties (parcel data)

Steps:

1. Begin with complete parcel data set.
2. Add I-35W land use codes to parcels
 - a. Convert from polygons to parcels (check centroid locations)
3. Convert Ramsey County land use codes to I-35W codes; add to parcels
 - a. Correct missing parcels (due to differing dates of parcels and attribute data; required some manual adjustments to parcel lines)

- b. Correct some parcel data without codes (common area around attached townhomes)
4. Make corrections to Ramsey County data (too much vacant and institutional)
 - a. Add parks from St. Paul data
 - b. Add parks from Ramsey County web site (park layer)
5. Merge water layer (from two sources) and code as water
6. Correct vacant land use around water bodies (to open space)
7. Add land use data from field-checking in other counties
 - a. Use Met Council data to confirm use
 - b. Remove Dakota County parcel within highway right-of-way; code others to vacant
8. Correct parcel slivers (usually changes to adjacent land uses)
9. Decide to leave government land uses (around Capitol) as institutional (not open space)
10. Carve out new open space parcels along Mississippi River
11. Recode parcels crossed by new Shepard Road
12. Check orthophotos or field-check for remaining mystery parcels
13. Convert to our 7 General Land Use Categories, as well as "Water" and "Other"
14. Based on Ramsey County land use codes, mark nighttime, social, retail, anti-pedestrian uses); field-check commercial parcels outside Ramsey County or use on-line property information search

In addition:

Decided, for land use, to use our detailed land use data for inside the context areas and use general Met Council data for areas outside the context areas (See Appendix 5C for more information on determining land uses in context areas).

Met Council residential uses were considered to be the following:

- Farmstead
- Seasonal/vacation
- Single family detached
- Manufactured housing park
- Single family attached
- Multifamily
- Mixed use residential

Roads

Sources: The Lawrence Group centerline data

Steps:

1. Remove random Macalaster College road segments (for intersection analysis, adjust these valences to reflect new intersection types)

Appendix 1F: Detailed instructions for Downloading and Cleaning Census Data

By Joel Koepp

Introduction

The US Census Bureau's American FactFinder website (<http://factfinder.census.gov>) is a quick and easy way to obtain data for normal geographies—cities, counties, census tracts, etc—but is very cumbersome for situations requiring non-standard geographies.

Documentation

<http://www.census.gov/prod/cen2000/doc/sf1.pdf>

<http://www.census.gov/prod/cen2000/doc/sf3.pdf>

The links above are the Technical Manuals for using Census Summary Files 1 and 3. They explain the geographies and contain the complete documentation for all variables, along with metadata.

Importing SF1 into Access

Begin by downloading the Access database template provided by the Census Bureau at <http://www.census.gov/support/2000/SF1/Access97.zip>

Open this database and update it to the most recent version of the Access file format. This is done by opening the Tools menu, then the Database Utilities submenu, and finally the Convert Database option. You will be prompted to save the file as a new database with a new name. At this point the database contains only empty tables that have the correct field names and types for the data they will eventually contain.

The raw data is downloaded from the Census FTP site (http://www2.census.gov/census_2000/datasets/) in compressed form. Individual files uncompress into very large text files with .uf1 file extensions. Each one must be renamed to have a .txt extension before importing into Access (e.g., rename mn00009.uf1 to mn00009.txt). The benefit of downloading the Census Access template is to get the import specifications built in. Import specifications ensure that when importing one of the text data files, all the fields are assigned the correct data type and receive the proper names.

Summary File 1 is split into 39 segments and 1 geographic header file. Chapter 7 of the Technical Manual contains a table matrix that shows the segment in which to find each table and individual variable. The most commonly used segments will be 1-11 and 37-39, which contain raw data at the block level. Segments 12-36 contain percentage tables.

With a segment file downloaded, uncompressed, and properly renamed, you can import it into the database.

1. From the Access menu, choose File→Get External Data→Import...
2. Change the dropdown box Files of Type to look for text files
3. Select the file to import (e.g., mn00001.txt for Segment 1) and click Import
4. In the Import Text Wizard that appears, clicked the Advanced button at the lower left
5. Click Specs to choose an import specification

6. Find the import specification that matches the segment being imported (in this case, SF10001 Import Specification) and click Open
7. Click OK
8. The wizard will correctly determine that the data is in a delimited format, so click Finish
9. When prompted to choose a table in which to store the data, select the existing empty SF10001 table, click Next, and then Finish
10. Right click on the table and choose Design View
11. Right click on the LOGRECNO field and select Primary Key
12. Click Save to preserve the changes in the table

The geographic header file (called SF1GEO in the database, it gets imported just like the segment files and has its own import specification) and one segment table are the minimum requirements to start making custom queries.

Open the Tools menu and choose Relationships. Add the SF1GEO table and one of the segment tables to the view. Drag the LOGRECNO field (which is the primary key in all tables) from SF1GEO to SF10001. This establishes the one-to-one relationship between the two tables based on that field. Create this relationship between SF1GEO and any other segment tables (SF10002, SF10003, etc) you wish to use.

Basic Queries

The first piece of information necessary in constructing a query of Census variables is the geography. It can be a county, a group of cities, a tract, a customized list of specific census blocks, or a combination of multiple geographies. To get the right records out of the database, a query requires the use of the proper summary level codes for the geographies. These are listed in a table on page 83 (Chapter 4) of the Technical Manual. The more common codes are 160 for a city, 080 for a census tract, and 101 for a census block.

The SF1GEO table contains one record for every census unit in a state. There are a number of fields that can be used in a query to identify a desired geography. The most helpful are SUMLEV, COUNTY, PLACE, TRACT, BLKGRP, BLOCK, and NAME. For example, to find all the census blocks in Ramsey County, you would build a query that looks for records where COUNTY = "123" and SUMLEV = "101" (this will be explained in more detail later).

Making Useful Extra Tables

After doing a few queries it will probably become apparent that searching for a particular county or city using codes like "123" and "40382" is not very intuitive. It may help save time in the long run to quickly create some tables that contain a correspondence between the county/place codes and the actual names.

In the main Access window, click on Queries. Double click the icon on the right labeled "Create query in Design View." In the blank query that appears, add the SF1GEO table and click Close. Click and drag the following fields into the columns at the bottom of the query: SUMLEV, COUNTY, and NAME. Under the

Field:	SUMLEV	COUNTY	NAME
Table:	SF1GEO	SF1GEO	SF1GEO
Sort:			
Show:	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Criteria:	"050"		
or:			

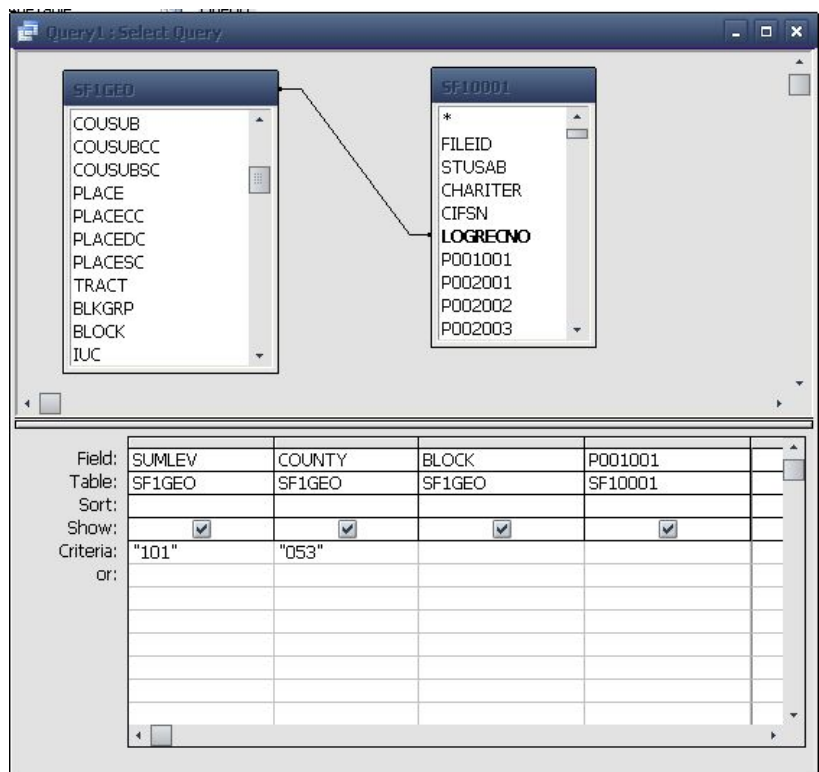
Criteria for SUMLEV, enter “050” (this is the summary level code for a county, as found on page 83 in Chapter 4 of the Technical Manual). Click the red exclamation point icon in the toolbar to run the query, which should display all the counties in the state. Save the query with a useful name.

Another useful lookup query to have is one that matches place codes to city names. In the main Access window, click on Queries. Double click the icon on the right labeled “Create query in Design View.” In the blank query that appears, add the SF1GEO table and click Close. Click and drag the following fields into the columns at the bottom of the query: SUMLEV, PLACE, and NAME. Under the Criteria for SUMLEV, enter “160” (this is the summary level code for a place, as found on page 83 in Chapter 4 of the Technical Manual). Uncheck the box under SUMLEV, because it doesn’t need to be displayed in the query results. Under the NAME column, set the Sort to be Ascending to display the city names alphabetically. Click the red exclamation point icon in the toolbar to run the query, which should display all the counties in the state. Save the query with a useful name.

Example Query: Population in all Hennepin County census blocks

This section will describe in detail how to use a query to identify a geography and link in a segment table to pull out a specific Census variable.

In the main Access window, click on Queries. Double click the icon on the right labeled “Create query in Design View.” In the blank query that appears, add the SF1GEO and SF10001 tables and click Close. The two tables should automatically be joined on the LOGRECNO field, assuming a relationship was established between them after they were imported. Click and drag the following fields from SF1GEO into the columns at the bottom of the query: SUMLEV, COUNTY, and BLOCK. Then click and drag the P001001 field from the SF10001 table into a column at the bottom. Under the Criteria for SUMLEV, enter “101” (this is the summary level code for a census block, as found on page 83 in Chapter 4 of the Technical Manual).



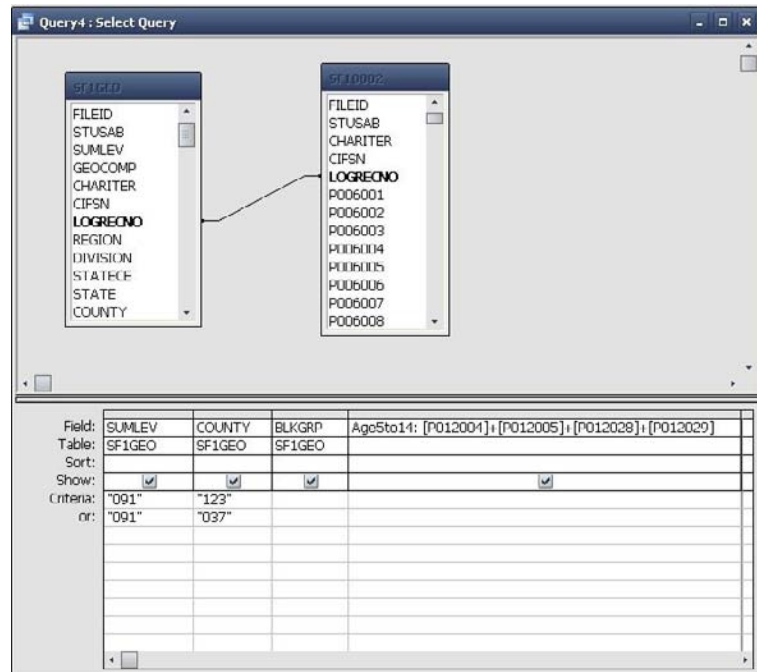
Uncheck the box under SUMLEV, because it doesn’t need to be displayed in the query results. Under the Criteria for COUNTY, enter “053” (found using the county names query created earlier), which will match Hennepin County. Click the red exclamation point icon in the toolbar to run the query.

Complex Queries and Calculating Fields

Age data is a very frequently used part of Census Summary File 1. In addition to simply querying variables, Access allows a user to perform calculations in a query and store the results in a new field. Since the age ranges are stored in separate variables for male and female, it is convenient to use an Access query that sums together a corresponding pair or pairs of variables (e.g., adding together P012003 and P012027 from table SF10002 would yield the total population of children under 5 years old). Similarly, several variables could be added together to identify a particular group of ages, like the key 18 to 34 year old male demographic.

As an example, the following steps make a query that counts the number of children between the ages of 5 and 14 at the block group level in Ramsey and Dakota Counties.

In the main Access window, click on Queries. Double click the icon on the right labeled “Create query in Design View.” In the blank query that appears, add the SF1GEO and SF10002 tables and click Close. The two tables should automatically be joined on the LOGRECNO field, assuming a relationship was established between them after they were imported. Click and drag the following fields from SF1GEO into the columns at the bottom of the query: SUMLEV, COUNTY, and BLKGRP. Under the Criteria for COUNTY, enter “037” and “123” on separate lines (these are the county codes for Dakota and Ramsey Counties, respectively, as found from the county code query created earlier). Under the Criteria for SUMLEV, enter “091” on the top two lines (this is the summary level code for a census block group, as found on page 83 in Chapter 4 of the Technical Manual). In an empty column at the end of the query, enter the following in the top row marked Field:



Age5to14: P012004+P012005+P012028+P012029

This will create in new field in the output of the query named Age5to14, and the values in that column will be the sum of the four variables that contain the male and female children of ages 5 to 9 and 10 to 14 (see Chapter 7, Table P12 on page 243 of the SF1 Technical Manual).

New fields can be created using mathematical operations of all kinds—for example, a user could sum together counts of various groups of the population and then calculate it as a percentage of the total population in one line, rather than having to do the work in a spreadsheet. Access also has many text manipulation functions, for concatenating multiple strings of text or stripping off characters from the left or right ends of a string.

Combining GIS and a Census Database

The ESRI website provides access to free Census GIS data for the entire United States. The Census Bureau's 2000 TIGER/Line data can be downloaded for individual counties after selecting a state. The TIGER/Line data contains line features (roads, railroads, etc), landmarks, and boundary files (census geographies, city and county boundaries, traffic analysis zones, etc).

Access Census data for download here:

http://arcdata.esri.com/data/tiger2000/tiger_download.cfm

Once a shapefile is downloaded, uncompressed, and added to an ArcGIS document, it is ready for analysis or processing. Each census geography shapefile will have in its Attribute Table a field called STFID which serves as the unique identifier for each feature. For example, a layer of census tracts will have an eleven character value in the STFID field, with each value unique to a particular census tract. A layer of block groups will have STFID values with twelve characters, and census blocks will have fifteen character STFID values.

The STFID is created by concatenating the values of the STATE, COUNTY, TRACT, BLKGRP, and BLOCK fields (as found in the SF1GEO table. The STATE portion is two characters, COUNTY is three characters, TRACT is six characters, BLKGRP is one character, and BLOCK is four characters. Note that the first character of the BLOCK field is identical to the BLKGRP value.

To construct a value in the Census database that will match the STFID values in the GIS shapefiles, use the following:

Tract:	[STATE] & [COUNTY] & [TRACT]
Block Group:	[STATE] & [COUNTY] & [TRACT] & [BLKGRP]
Block:	[STATE] & [COUNTY] & [TRACT] & [BLOCK]

Appendix 4A: Modified Boarnet-Day Inventory, Now the Irvine-Minnesota Inventory

By Ann Forsyth drawing on collaborative work by Kristen Day, Marlon Boarnet, and Mariela Alfonzo

Note, this is the inventory as used. However, a revised version has been created and will be available on the Active Living Research web site. Called the Irvine-Minnesota Urban Design Inventory, it includes reliability information.

In the inventory as used, a number of coding protocols were used to clarify skipped items in particular and a revised version has been prepared that removes the “skip question and code as 9” type items but instead provides a skip / not applicable option in each question. A separate paper is available that describes how this inventory was used (Forsyth et al 2004a).

It should be noted that the inventory was conducted on a 20% sample of roads with pedestrian access with divided roads treated as one road (if both sides were selected, one was removed and a new random segment drawn). Because the road data contained a number of very small segments, those less than 50 feet long were excluded.

Use 8 not slash to indicate NA; in excel code a skipped answer as 9 unless otherwise instructed below

early line numbering to track data

Date

1 2 3 4 5 6 7 8 9 10

Observer	1	2	3	4	5	6	7	8	9	10
SEGMENT >	1									
Answer questions 1-6 based on this end of the segment										
INTERSECTION--FILL IN!!!	3									
Neighborhood Identification	4									
1. Are there monuments or markers including neighborhood entry signs that indicate that one is entering a special district or area?										
yes = 1; no = 0										
Street Crossing	6									
2a. Consider the places on the segment that are intended for pedestrians to cross the street. Are these places marked for pedestrian crossing?	7									
All = 3; Some = 2; none = 0; NA = 8										
If 2a = "None" or "N/A", skip to question 3 [after coding 2b as 0]	8									
2b. What type of marking do the crosswalks have? Mark all that apply.	9									
White painted lines	10									
yes = 1; no = 0										
Colored painted lines	11									
yes = 1; no = 0										
Zebra striping	12									
yes = 1; no = 0										
Different road surface or paving (e.g. tiles, colored concrete, marble, etc)	13									
yes = 1; no = 0										
Other	14									
yes = 1; no = 0										
3. Are there curb cuts at all places where crossing is expected to occur?	15									
All = 3; Some = 2; none = 0; NA = 8										
4. What type of traffic/pedestrian signal(s)/system(s) is/are provided? Mark all that apply.	16									
Traffic signal	17									
yes = 1; no = 0										
Stop sign	18									
yes = 1; no = 0										
Yield sign	19									
yes = 1; no = 0										
Pedestrian activated signal	20									
yes = 1; no = 0										
Pedestrian crossing sign	21									
yes = 1; no = 0										
Pedestrian overpass/underpass/bridge	22									
yes = 1; no = 0										
None	23									
yes = 1; no = 0										
5. For an individual who is on this segment, how safe (traffic wise) do you think it is to cross the street from this segment?	24									
Pretty/very safe = 1; not very safe/unsafe = 0 Cul de sac = 8										
6. For an individual who is on this segment, how convenient (traffic wise) do you think it is to cross the street from this segment?	25									
Pretty/very convenient = 1; not very/inconvenient = 0; cul de sac = 8										
Answer questions 7-11 while standing at the beginning of the segment	26									
Neighborhood Identification	27									
7. Does the segment have banners that identify the neighborhood?	28									
Some/a lot = 3; few = 2; none = 0										
Street Characteristics	29									
8a. Is this a pedestrianized street?	30									
yes = 1; no = 0										
8b. Is the street a ...	31									
one way = 1; two way = 2										
9. Is this segment an alley?	32									
yes = 1; no = 0										

Use 8 not slash to indicate NA; in excel code a skipped answer as 9 **unless otherwise instructed below**

	early line numbering to track data	Date	1	2	3	4	5	6	7	8	9	10
10. How many vehicle lanes are there for cars? (include turning lanes) [changed scale]	33	count										
Views	34											
11a. Is this segment characterized by having a significant open view of an object or scene that is not on the segment? The view must be a prominent one.	35	yes = 1; no = 0										
If 11a = No, skip to question 12.	36											
11b. How attractive is the open view?	37	3 = Attractive; 2 = neutral; 1 = Unattractive.										
Begin walking along segment to answer questions 12-68												
12c. How many of the buildings in this segment contain vertical mixed use, that is, the building has different land uses on different floors of the building?	39	Some/a lot = 3; few = 2; none = 0; N/A no buildings > 1 story = 8										
12d. Mark if any of these building types are present (focusing on the form of the building).	40											
Big box shops (includes super stores or warehouse stores)	41	yes = 1; no = 0										
Shopping mall	42	yes = 1; no = 0										
Strip mall/row of shops	43	yes = 1; no = 0										
Drive-thru	44	yes = 1; no = 0										
None of the above	45	yes = 1; no = 0										
13a. Mark off all types of public space(s) on this area and how attractive it is	47	3 = attractive; 2 = neutral; 1 = unattractive; 0 = no space; above										
Park/playground	48	above										
Playing or sport field	49	above										
Plaza /square /courtyard	50	above										
Public garden	51	above										
Beach	52	above										
Other	53	above										
13d. Is it possible for the general public to use the public space(s)?	54	unclear = 2; yes = 1; no = 0										
Other Land Uses	55											
14. How many of these land uses are present on this segment?	56											
Bars/night clubs	57	Some/a lot = 3; few = 2; none = 0										
Adult uses	58	Some/a lot = 3; few = 2; none = 0										
Check cashing stores/pawn shops/bail bond stores	59	Some/a lot = 3; few = 2; none = 0										
Liquor stores	60	Some/a lot = 3; few = 2; none = 0										
15. How many of the following gathering places are on this segment?	61											
Restaurants	62	Some/a lot = 3; few = 2; none = 0										
Coffee shops	63	Some/a lot = 3; few = 2; none = 0										
Libraries/bookstores	64	Some/a lot = 3; few = 2; none = 0										
"Corner" store	65	Some/a lot = 3; few = 2; none = 0										

Use 8 not slash to indicate NA; in excel code a skipped answer as 9 unless otherwise instructed below

	early line numbering to track data	Date	1	2	3	4	5	6	7	8	9	10
Art or craft galleries	66	Some/a lot = 3; few = 2; none = 0										
Farmers market	67	yes = 1; no = 0										
16. Are these nature features present on this segment?												
Open field/golf course	68	yes = 1; no = 0										
Lake/pond	69	yes = 1; no = 0										
Fountain/reflecting pool	70	yes = 1; no = 0										
Stream/River/Canal/Creek	71	yes = 1; no = 0										
Forest or woods	72	yes = 1; no = 0										
Mountain or hills	73	yes = 1; no = 0										
Barriers	74											
17a. Are the following barriers present on this segment. Check all that apply. Mark response in column A, and whether barrier can be overcome e.g. there's a pedestrian bridge.		0 = no barrier; 1 = can be overcome; 2 can be somewhat overcome; 3 can not be overcome										
Highway (elevated or below ground)	75	above										
Railroad track	76	above										
Impassable land use (e.g., gated community, major industrial complex, etc.)	77	above										
River	78	above										
Drainage ditches	79	above										
Fences/walls	80	above										
Road with 6 or more lanes	81	above										
Other	82	above										
Sidewalks	83	above										
18a. How many sides of the street have sidewalks?	84											
18b. Is the sidewalk complete on one or both sides?	84a	Count 1 or 2										
18c. What is the predominant sidewalk width? (If no predominant width, mark all that apply)		yes = 1; no = 0; 8 = NA										
18d. What is the condition or maintenance of the sidewalk?	85	0 = under 4 ft; 1 = 4-7 ft; 2 = 7+; 8 = NA (no sidewalk)										
18e. Is there a decorative or unique paving on that covers most or all of the sidewalk on the segment? (e.g., bricks, tile, etc.)	86	0 = Poor; 1 = moderate or good; 2 = under repair										
18f. Determine how much of the sidewalk is covered by these features that provide protection from sun, rain, and/or snow.	87	yes = 1; no = 0										
Arcades	88	1 = some/ much of sidewalk covered; 0 = No/little covered;										
Awnings	89	above										
Other	90	above										
18g. Is there is a buffer (for example, parked cars, landscaped "buffer" strip, etc.) between sidewalk or street.	91	above										
IF 18g = "No buffer", skip to question 19 (after coding 18h as 0).	92	2 = both sides; 1 = 1 side; 0 = no buffer										
18h. Mark the forms of buffers that are present. Mark all that apply. **must be present along most or the entire segment on 1+ sides**	93											
	94											

Use 8 not slash to indicate NA; in excel code a skipped answer as 9 **unless otherwise instructed below**

	early line numbering to track data	Date	1	2	3	4	5	6	7	8	9	10
Angled parking of cars	95	yes = 1; no = 0										
Parallel parking of cars	96	yes = 1; no = 0										
Street trees that run along the most of or the entire segment, between sidewalk and the street	97	yes = 1; no = 0										
Landscape "buffer" strip or bollards (posts) between sidewalk and street	98	yes = 1; no = 0										
Other	99	yes = 1; no = 0										
19. Are there sidewalks/greenbelts/trails/paths other than sidewalks along street?	100	yes = 1; no = 0										
Bicycle Lanes	101											
20a. Are there bicycle lanes on the segment?	102	yes = 1; no = 0										
If 20a = "No", skip to question 21.	103											
20b. How are the bicycle lanes demarcated?		On road, painted line/ reflectors =3; on road physical separation = 2; off road = 1										
Mld Block Crossing	104											
21a. Is there a marked mid-block crosswalk for pedestrians?	105	yes = 1; no = 0										
If 21a = No, skip to question 22 [After coding 21b as 0].	106											
21b. What type of marking does the crosswalk have? Mark all that apply	107											
White painted lines	109	yes = 1; no = 0										
Colored painted lines	110	yes = 1; no = 0										
Zebra striping	111	yes = 1; no = 0										
Different road surface or paving (e.g. tiles, colored concrete, marble, etc)	112	yes = 1; no = 0										
Other	113	yes = 1; no = 0										
Steepness	114											
22. How steep or hilly is this segment? Mark all that apply.	115	steep = 1; flat or gentle = 0										
Sidewalk Amenities	116											
23. Are there outdoor dining areas (e.g. cafes, outdoor tables at coffee shops or plazas, etc) located on the segment?	117	Some/a lot = 3; few = 2; none = 0										
24a. Indicate how many of each of the following street furniture/sidewalk amenities is/are present on the segment.	118											
Benches (not a bus stop), chairs and/or ledges for sitting	119	Some/a lot = 3; few = 2; none = 0										
Bus stops with seating	120	Some/a lot = 3; few = 2; none = 0										
Heat lamps	121	Some/a lot = 3; few = 2; none = 0										
Bike racks	122	Some/a lot = 3; few = 2; none = 0										
Trash cans	123	Some/a lot = 3; few = 2; none = 0										
If 24a = "None" for all types of street furniture, skip to question 25.												
24b. Looking at the street furniture on this segment overall, would you describe it as generally attractive?	125	3 = Attractive; 2 = neutral; 1 = Unattractive										

Use 8 not slash to indicate NA; in excel code a skipped answer as 9 unless otherwise instructed below

	early line numbering to track data	Date	1	2	3	4	5	6	7	8	9	10
25. Are there obvious public restrooms on this segment that are clearly open to the public?	126	yes = 1; no = 0										
Buildings	127											
28. How many buildings on this segment can you enter directly from the street?	128	Some/a lot = 3; few = 2; none = 0										
31. Are there abandoned buildings or lots on this segment?	129	Some/a lot = 3; few = 2; none = 0										
32a. Does at least 50% of the segment have buildings?	130	yes = 1; no = 0										
If 32a = "No", skip to question 33.	131											
Windows	132											
32b. From how many buildings on the segment can pedestrians easily be seen?	133	0 = none, 1 = < 50%, 2 = > 50%										
33. How many buildings on this segment have windows with bars? (proportion)	134	Some/a lot = 3; few = 2; none = 0; NA = 8										
Other features of buildings	135											
34. How many buildings on this segment have front porches? (proportion--porches you can sit on)	136	Some/a lot = 3; few = 2; none = 0; NA = 8										
35. How many buildings on this segment have balconies facing the segment? (proportion)	137	Some/a lot = 3; few = 2; none = 0; NA = 8										
36. How much of the segment has blank walls or buildings with blank walls?	138	All = 3; Some = 2; none = 0; NA = 8										
37a. On this segment, what percentage of the properties contain fences/walls/hedges/elevated ground that separate the building(s) or property(ies) from the street? (Hedges must be acting as fences/walls to be counted)	139	0 = none, 1 = < 50%, 2 = > 50%										
If 37a = "none", skip to question 38a.	140											
37b. Describe the attractiveness overall of the walls and/or fences on this segment.	141	3 = Attractive; 2 = neutral; 1 = Unattractive										
37c. What is the approximate height of the fences/walls on the segment? Mark all that apply	142											
Less than 4 feet	143	yes = 1; no = 0										
4 feet and over	144	yes = 1; no = 0										
Garages	145											
38a. How many buildings have garage doors facing the street?	146	Some/a lot = 3; few = 2; none = 0; NA = 8										
If 38a = "none or one" or "N/A", skip to question 39a.	147											
38b. How prominent are most garage doors when looking at the front of the buildings?	148	Very = 3; somewhat = 2; not very/not visible = 0										
Parking	149											
39a. Is there a parking structure visible on this segment (do not include parking structures that are completely underground)?	150	yes = 1; no = 0										
If 39a = "No" skip to question 40a.	151											

Use 8 not slash to indicate NA; in excel code a skipped answer as 9 unless otherwise instructed below

	early line numbering - to track data	Date	1	2	3	4	5	6	7	8	9	10
39b. Looking at the front of the parking structure on the street level floor, what is the predominant use that is visible to you?	152	Parking = 2; varied = 1; not parking/other uses = 0										
39c. What percentage of the segment is covered by the parking structure?	153	all or almost all = 3; about half = 2; less than half = 1										
40a. Is there a parking lot that fronts/faces the street on either side of the segment?	154	2 = both sides; 1 = 1 side; 0 = no lots										
If 40a = "neither side has a parking lot", skip to question 41.	41.											
40c. How much of the side(s) that has the parking lot fronting the street is(are) covered by the parking lot? (Consider the largest parking lot if more than one)	157	all or almost all = 3; about half = 2; less than half = 1										
40d. How many trees are there in the parking lot, compared to the number of parking spaces?	158	Some/a lot = 3; few = 2; none = 0										
Driveways	159											
41. How many driveways are visible on the segment?	160	Some/a lot = 3; few = 2; none = 0										
Maintenance	161											
42a. Describe the general maintenance of the buildings on this segment.	162	3 = Attractive; 2 = neutral; 1 = Unattractive; 8 = NA										
42b. Describe the general maintenance of the landscaping on this segment.	163	3 = Attractive; 2 = neutral; 1 = Unattractive; 8 = NA										
If 42b = unattractive or NA, skip to question 44.												
43. How much of the segment contains well-maintained (fair or good) landscaping?	165	1 = < 50%; 2 = > 50%										
44. How much graffiti is apparent on this segment?	166	Some/a lot = 3; little = 2; none = 0										
45. How much litter is apparent on this segment?	167	Some/a lot = 3; little = 2; none = 0										
46. Are there dumpsters visible on this segment?	168	Some/a lot = 3; few = 2; none = 0										
47. Is there visible electrical wiring overhead on the segment?	169	Some/a lot = 3; few = 2; none = 0										
Lighting	170											
48b. Are the outdoor light fixtures mostly less than or greater than 13 feet tall (i.e. one story)?	171	1 = more than 13; 0 = less										
Freeways	172											
49. Is there a freeway overpass/underpass connected to this segment?		under a freeway overpass = 3; next to freeway = 2; IS a freeway overpass = 1; none of the above = 0										
Traffic Features	173											
50. What is the posted speed limit on this segment? Only include those on the segment itself.	174	Use number; 8 = not posted										
51. Are there measures on this segment that could slow down traffic? Mark all that apply.	175											
Speed bump/speed hump/raised crosswalk; or dips (that are intended to slow down traffic)	176	yes = 1; no = 0										
Rumble strips or bumps (includes dots, reflectors, raised concrete strips, etc.)	177	yes = 1; no = 0										
Curb bulb out/curb extension	178	yes = 1; no = 0										
Traffic circle/roundabout	179	yes = 1; no = 0										
	180	yes = 1; no = 0										

Use 8 not slash to indicate NA; in excel code a skipped answer as 9 unless otherwise instructed below

	early line numbering + to track data	Date	1	2	3	4	5	6	7	8	9	10
Median	181		yes = 1; no = 0									
Street Trees (that run along most or the entire segment – do not have to be on both sides, can be in yards)			yes = 1; no = 0									
Angled/ On-street parking (that runs along most or the entire segment - does not have to be on both sides of segment)	182		yes = 1; no = 0									
Other	183		yes = 1; no = 0									
52a. Is there a cul-de-sac or permanent street closing on this segment?	184		yes = 1; no = 0									
If 52a = "No" skip to question 53.	186		yes = 1; no = 0									
52b. Is there a pedestrian access point or cut through point that allows pedestrians to go from one segment to another even though vehicular traffic may not be able to?	187		yes = 1; no = 0; Don't know = 7									
Architecture/Design	188											
53. Rate the attractiveness of the segment. (design + maintenance)	189		3 = Attractive; 2 = neutral; 1 = Unattractive									
54. Does this segment have buildings that appear to be historic? (old + detailed)	190		yes = 1; no = 0; NA = 8									
55. How interesting is the architecture/urban design of this segment?	191		3 = interesting; 2 = somewhat int.; 1 = Uninteresting									
56. How alike are the designs of the buildings on the segment?	192		2 = all similar design; 1 = range of different designs; 8 = NA (0-1 buildings)									
If 56 = "All of similar designs" or "N/A" skip to question 58.	193											
57. How much do the houses or buildings appear to fit or go together (how compatible they are), in terms of architectural appearance? (Buildings do not have to be exactly the same to go together)	195		Some/a lot = 3; a little = 2; none = 0									
Other features of the segment	196											
62. How many street vendors or stalls are on this segment? (do not count newspaper racks, there must be a person vending)	197		Some/a lot = 3; few = 2; none = 0									
63. Is there public art that is visible on this segment?	198		yes = 1; no = 0									
64. Are there billboards present on this segment?	199		Some/a lot = 3; few = 2; none = 0									
People	200											
65. How many other people were present outdoors while you were observing this segment?	201		Some/a lot = 3; few = 2; none = 0									
If 65 = "None" skip to question 67.	202											
66. Thinking of the people on this segment, how safe do you feel walking on this segment?	203		Pretty/very safe = 1 not very safe/ unsafe = 0									
Dogs	204											
67. Are there any loose/unsupervised/barking dogs on this segment that seem menacing?	205		yes = 1; no = 0									
Olfactory Character	206											
68. Is the dominant smell unpleasant?	207		yes = 1; no = 0									

Use 8 not slash to indicate NA; in excel code a skipped answer as 9 unless otherwise instructed below

Early line numbering - to track data	Date	1 2 3 4 5 6 7 8 9 10									
		Neighborhood Identification (OTHER END OF SEGMENT)									
1. Are there monuments or markers including neighborhood entry signs that indicate that one is entering a special district or area?											
Street Crossing	209										
210											
2a. Consider the places on the segment that are intended for pedestrians to cross the street. Are these places marked for pedestrian crossing?	211										
If 2a = "None" or "N/A", skip to question 3 [after coding 2b as 0]	212										
2b. What type of marking do the crosswalks have? Mark all that apply.	213										
White painted lines	214										
Colored painted lines	215										
Zebra striping	216										
Different road surface or paving (e.g. tiles, colored concrete, marble, etc)	217										
Other	218										
3. Are there curb cuts at all places where crossing is expected to occur?	219										
4. What type of traffic/pedestrian signal(s)/system(s) is/are provided? Mark all that apply.											
Traffic signal	220										
221											
Stop sign	222										
Yield sign	223										
Pedestrian activated signal	224										
Pedestrian crossing sign	225										
Pedestrian overpass/underpass/bridge	226										
None	227										
5. For an individual who is on this segment, how safe (traffic wise) do you think it is to cross the street from this segment?											
228											
6. For an individual who is on this segment, how convenient (traffic wise) do you think it is to cross the street from this segment?	229										

Appendix 5A: Ramsey County Land Use Codes

Land Use Code	Type	Land Use Description
109	A	GREENHOUSES, VEGETABLES & FLORACULT.
300	I	INDUSTRIAL, VACANT LAND
310	I	FOOD&DRINK PROCESS PLANTS AND STORAE
320	I	FOUNDERIES&HEAVY MANUFACT PLANTS
340	I	MANUFACTURING & ASSEMBLY LIGHT
390	I	GRAIN ELEVATORS
399	I	OTHER INDUSTRIAL STRUCTURES
400	C	COMMERCIAL VACANT LAND
401	M	APARTMENTS 1-9 RENTAL UNITS
402	M	APARTMENTS 10-19 RENTAL UNITS
403	M	APARTMENTS 20-49 RENTAL UNITS
404	M	APARTMENTS 50 OR MORE UNITS
405	M	APARTMENT VACANT LAND
406	M	APARTMENT MISC IMPROVEMENTS
410	C	MOTELS AND TOURIST CABINS
411	C	HOTELS
412	C	NURSING HOMES & PRIVATE HOSPITALS
415	C	TRAILER OR MOBILE HOME PARK
420	C	SMALL (UNDER 10,000SF) DETACH RETAI
421	C	SUPERMARKETS
422	C	DISCOUNT STORES & JR. DEPT STORES
423	C	MEDIUM DETACHED RETAIL
424	C	FULL LINE DEPARTMENT STORES
425	C	NEIGHBORHOOD SHOPPING CENTER
426	C	COMMUNITY SHOPPING CENTER
428	C	VETERINARY CLINIC
429	C	OTHER RETAIL STRUCTURES
430	C	RESTURANT, CAFETERIA, AND/OR BAR
431	C	SMALL STRIP CENTER
432	C	CONVENIENCE STORE
435	C	DRIVE-IN REST/FOOD SERVICE FACILITY
437	C	DAY CARE CENTERS
441	C	FUNERAL HOMES
442	C	MEDICAL CLINICS AND OFFICES
444	C	FULL SERVICE BANKS
447	C	OFFICE BUILDING 1-2 STORIES
448	C	OFFICE BULD 3 OR MORE STORIES WALKUP
449	C	OFFICE BULD 3 OR MORE STORIES ELEVAT
450	C	CONDOMINIUM OFFICE UNITS
451	C	GAS STATION
452	C	AUTOMOTIVE SERVICE STATION
453	C	CAR WASHES
454	C	AUTO CAR SALES AND SERVICES
456	C	PARKING GARAGE STRUCTURE & LOTS
458	C	CI/CONDO/CO-OP NON-TAX OUTLOT
460	C	THEATERS

463	C	GOLF COURSES
464	C	BOWLING ALLEYS
465	C	LODGE HALLS AND AMUSEMENT PARKS
479	C	FLEX INDUSTRIAL CENTER
480	C	COMMERCIAL WAREHOUSES
481	C	MINI WAREHOUSE
482	C	COMMERCIAL TRUCK TERMINALS
499	C	OTHER COMMERCIAL STRUCTURES
500	R	RESIDENTIAL, VACANT LAND, LOT
501	E	RESID/EXEMPT VACANT LAND
510	R	SINGLE FAMILY DWELLING, PLATTED LOT
511	R	RES/EXEMPT SINGLE FAMILY DWELLING
515	R	TWO RESIDENCES ON ONE PARCEL
520	R	TWO FAMILY DWELLING, PLATTED LOT
521	E	RES/EXEMPT MULTI FAMILY DWELLING
525	R	CONVERSION
530	R	THREE FAMILY DWELLING, PLATTED LOT
540	R	DOUBLE DWELLING
545	R	1/2 DOUBLE DWELLING
546	E	RES/EXEMPT 1/2 DOUBLE DWELLING
550	R	CONDO/CO-OP
552	R	CONDO/CO-OP GARAGE OR STORAGE
555	R	CONDO/CO-OP NON-TAX OUTLOT
570	R	TOWNHOME-INNER
573	R	TOWNHOME-DETACHED
575	R	TOWNHOME-OUTER
577	R	TOWNHOME NON-TAX OUTLOT
579	R	RESIDENTIAL, TOWNHOME VACANT
600	E	EXEMPT PROPERTY OWNED BY USA
610	E	EXEMPT PROPERTY OWNED BY STATE OF MN
615	E	EXEMPT PROPERTY OWNED BY MET COUNCIL
620	E	EXEMPT PROPERTY OWNED BY COUNTIES
635	E	FIRESTATIONS
640	E	EXEMPT PROPERTY OWNED BY MUNICIPALS
641	E	EXEMPT LAND
642	E	EXEMPT CLINICS
644	E	SPORT/PUBLIC ASSEMBLY FACILITY
645	E	EXEMPT HRA VACANT LAND
646	E	EXEMPT CULTURAL & NATURE EXHIBITS
647	E	EXEMPT COMMUNITY RECREATIONAL FAC.
649	E	LIBRARY
650	E	EXEMPT PROPERTY OWNED BY BD OF EDUC.
660	E	EXEMPT PROPERTY OWNED PARK DIST.PUB
670	E	EXEMPT PROP OWNED BY PRIVATE SCHOOLS
680	E	CHARITABLE EXEMPT HOSP./NURSG HOMES
682	E	WELFARE/CHARITABLE FACILITY
685	E	CHURCHES ETC PUBLIC WORSHIP PRIVE
687	E	EXEMPT OFFICE BUILDINGS
690	E	GRAVEYARDS MONUMENTS, CEMETERIES
830	U	COMM LD&IMPRO OWN BY PUB UTI TH RAIL
840	U	RAILROAD REAL PROP USED IN OPERATION

850	U	RAILROAD REAL PROP NOT USED OPERATOS
880	U	PUB UTIL PER PROP OTHER THAN RRS
OTHERS NOT PRESENT IN STUDY SITES		
101	A	CASH GRAIN OR GENERAL FARM
108	A	NURSERIES
120	A	TIMBER OR FOREST LANDS
190	A	OTHER AGRICULTURAL USE
370	I	SMALL SHOPS (MACHINE, TOOL & DIE ETC)
407	M	FRATERNITY/SORORITY HOUSE
427	C	REGIONAL SHOPPING CENTER
440	C	DRY CLEANING PLANTS & LAUNDRIES
445	C	SAVINGS AND LOAN
457	C	PARKING RAMP
461	C	DRIVE-IN THEATERS
462	C	GOLF DRIV RANGE & MINI GOLF COURSES
485	C	RESEARCH AND DEVELOPMENT FACILITY
490	C	MARINE SERVICE FACILITIES
496	C	MARINA (SMALL BOAT)
509	R	RESID, NEW PLATS INITIAL YEAR
519	R	RESID, NEW PLATS INITIAL + 1/3 DIFF
529	R	RESID, NEW PLATS INITIAL + 2/3 DIFF
539	R	RESID, NEW PLATS THIRD YEAR
549	R	RESID, PROBLEM VACANT PINS
559	R	RESIDENTIAL, CONDO/CO-OP VACANT
560	R	MOBILE HOME ON REAL ESTATE
598	E	EXEMPT OTHER RESIDENTIAL
599	R	OTHER RESIDENTIAL
625	E	ST PAUL AIRPORT & MAC PROPERTY
695	E	SKYWAYS
821	U	VACANT LAND

Appendix 5B: I-35W Corridor Coalition Land Use Codes

AG	Agriculture
SFD	Single Family Detached
SFA	Single Family Attached
MF	Multiple Family
MH	Mobile Home Park
R	Rural Residential
NC	Neighborhood Commercial
CC	Community Commercial
RC	Regional Commercial
HC	Highway Convenience
OFC	Office
MU	Mixed Use
LI	Light Industrial
HI	Heavy Industrial
IN	Institutional
SRO	Outdoor Sport/Recreation
SRI	Indoor Sport/Recreation
OSN	Natural Open Space
OSP	Passive Open Space
ROW	Right-of-Way
RR	Railway
UTL	Utility
VAC	Vacant
WAT	Water
AP	Airport

Appendix 5C: Determining Land Uses for Context Areas and Buffers

By Jason Zimmerman

Our land use analysis was the result of the merging of two separate measurement areas. Outside of our Context Areas, land use data was based on the categories created as part of the Metropolitan Council's 2000 Land Use data set. Within the Context Areas, a more detailed set of steps was carried out to achieve the most accurate data possible.

Process for determining Land Uses for parcels in our Context Areas developed as follows:

1. Began with I-35W land use codes for parcels in Coalition cities
2. Added parcel data from other Ramsey County cities
3. Translated Ramsey County land use codes to I-35W land use codes (used I-35W land use definitions and best estimates as to comparable categories)
4. Some Vacant and Institutional land uses were really Park and Recreation land uses. Using a combination of a St. Paul parks layer, an on-line Ramsey County park map, and county orthophotos, large vacant areas were checked to see if they should be recoded as Park and Recreation. They were recoded if other sources indicated they were parks – vacant parcels that were not clearly identified elsewhere as parks were left vacant.
5. Manually corrected some Ramsey County parcels with no codes (e.g., land surrounding townhomes, typically common areas, re-coded from Vacant to Single Family Attached)
6. Manually corrected small slivers created through merging and clipping of parcel data sets (coded to match surrounding land uses)
7. Added Hennepin, Dakota, and other Anoka County parcels and land uses field-checked by staff
8. Railroad parcels inconsistently classified across cities and counties. In some places they were some coded Exempt Land, others Operational RR, and still others Non-Operational RR. We did not change this. As a result, some railroad parcels are coded Tax Exempt and others Industrial.
9. When in doubt, used Met Council 2000 land use data, on-line property tax information, and orthophotos to check questionable parcels
10. Overlaid Ramsey County water layer (most detailed available)
11. Outside Ramsey County, overlaid Met Council water layer (more general)
12. Parcel remnants around ponds were reassigned to open space categories—some had been vacant (see below – Image 1 has the parcel surrounding the pond coded Vacant; Image 2 is the orthophoto that shows the area is really open space; Image 3 is the corrected data with the parcel coded as open space)



Process for determining Land Uses for parcels outside our Context Areas (Buffers) developed as follows:

1. Had to assign Met Council land use data from polygons to Regional parcel data using centroids and a spatial join – this meant we had to correct by hand when parcel centroids did not fall within land use polygons

The image below demonstrates this point. The colored areas are land use polygons, the thin grey lines show parcel boundaries, and the points are parcel centroids. Oddly-shaped parcels, such as the one outlined in purple, have centroids that may not fall within the correct land use polygon. Here, the parcel centroid (highlighted in purple) falls inside the lake. Assigning the underlying land use to the centroid, and thus to the parcel, would result in the large open space parcel being coded as Water. Instead, the centroid was manually coded as Park and Recreation.



2. Converted general Met Council land use categories to our seven major land use categories

Met Council Code	Met Council Land Use	RWJF Land Use
100	Agriculture	OTHER
111	Farmsteads	RESIDENTIAL
112,113,116	Single Family Residential	RESIDENTIAL
114,115	Multi-Family Residential	RESIDENTIAL
120	Commercial - Retail	COMMERCIAL
130	Commercial - Office	OFFICE

141	Mixed Use - Residential	OFFICE
142	Mixed Use - Industrial	INDUSTRIAL
143	Mixed Use - Commercial	COMMERCIAL
151	Industrial and Utility	INDUSTRIAL
153	Extractive	INDUSTRIAL
160	Institutional	TAX EXEMPT
170	Park, Rec, and Preserve	PARK AND RECREATION
173	Golf Course	PARK AND RECREATION
201	Major Highway	OTHER
202	Railway	INDUSTRIAL
203	Airport	OTHER
210	Undeveloped	VACANT
220	Water	WATER

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ⁱ Gross density was measured over a land area, i.e. excluding water, using census blocks. Where blocks were cut by the edge of a focus area, population was apportioned in proportion to their area (e.g. if 40% of a census block was in the focus area, it received 40% of its population). Median block size as calculated for census blocks that had a centroid within the focus area. More detail on measurement is forthcoming in a protocol document.

"The study sites were selected to represent a subset of the most extreme areas—ranking high or low on each of these two dimensions—nine sites with high density and small blocks, nine with high density and big blocks, nine with low density and small blocks, and nine with low density and big blocks. Of course, given North American development patterns densities are not particularly extreme in an international sense. Low population density was set at below 5 persons per gross acre for a 0.5*0.5mile area, high density we defined as 10 per acre and above. All density calculations excluded the land area in water. Originally we had wanted to be closer to 13 persons/ acre but there were not enough candidates from which to sample, particularly for large blocks. Small median block size was defined as below 5 acres which was related to standard block sizes in the area. Large blocks were larger than 8 acres. Areas also had to have at least 20 percent of their land area in residential land use" (Forsyth et al 2004a).

ⁱⁱ One additional block was cut out of the sample because its population was only 60 people.