The Walkable-Bikeable Communities Analyst Extension for ArcView GIS 3.x

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Abstract:

Recent research in transportation, urban planning, and public health has focused on walkability and bikeability of the built environment. While a growing body of work is increasing the understanding of the relationship between the built environment and activity, more work needs to be done to operationalize and quantify "walkability" and "bikeability" using objectively measured values.

The Urban Form Laboratory at the University of Washington's College of Architecture and Urban Planning (Seattle, USA) has developed an ArcView GIS 3.x extension for quantifying objective measures of urban form that have been useful in modeling preferences for walking and cycling in different neighborhoods within the Seattle area. The WBC Analyst uses standard buffer and network analyses as well as some novel algorithms to generate these quantitative measures.

Output from the extension, when coupled with a telephone survey on socio-demographics, exercise, and activity levels, shows promising results for understanding walkability and bikeability in the fields of urban planning, public health, and transportation.

The extension can be obtained at http://gis.washington.edu/phurvitz/wbc.

1. *Introduction/Background*

A disturbing rise in body mass index has been identified in a number of places worldwide. Obesity in the US has increased steadily over the last decade as has obesity-related illnesses such as hypertension, heart disease, diabetes (Aguilar-Salinas *et al.* 2001). Median body mass index increased more than 10% from 1990 to 2002 (CDC 1990-2002). The causes of this trend are manifold, but most probably driven by an increase in caloric intake (Briefel and Johnson 2004) coupled with a decrease in physical activity (Mokdad *et al.* 2001).

Substantial evidence exists linking even moderate physical activities such as walking with both mental and physical health benefits (e.g., Pollock 1978; LaCroix *et al.* 1996; Oja, Vuori, and Paronen 1998; Sesso *et al.* 1999). The US Surgeon General recommends 20 minutes of vigorous physical activity three or more times a week or 30 minutes of moderate physical activity five times a week (CDC 1996) as part of a basic health maintenance program. Walking is one of the suggested activities for obtaining moderate amounts of exercise. Although moderate exercise may have little effect on weight loss among the overweight, increased levels of activity can increase levels of vigor and lower the incidence of negative health outcomes.

Although walking is a good way to get moderate exercise, not all locations are either suitable or friendly for walking. Many locations within urban, suburban, and rural locations pose either difficulties or direct physical threats to walkers. Problems such as lack of sidewalks, insufficient crosswalks, dangerous intersections, fast traffic, and low levels of connectivity can decrease the desire to walk.

The social-ecological approach (Stokols 1992) is becoming increasingly popular as a way of conceptualizing the relationship between environment and behavior. Evidence is mounting that the composition and configuration of the urban environment has an effect on physical and mental health (Sturm and Cohen 2004). The design of communities therefore may have a profound impact on propensity to get exercise through walking, and hence an effect on the physical and mental health of residents.

The specific elements of urban form that are most conducive to walking behavior are not yet known with a high degree of certainty. A number of studies have looked at different environmental audit instruments for assessing walkability and bikeability (see Moudon and Lee 2003 for a synopsis). Many of these studies have used both objective and subjective measures as independent variables to predict walking and cycling. Some recent studies (Ewing *et al.* 2003; Saelens, Sallis, and Frank 2003; Frank, Andresen, and Schmid 2004; Frank and Engelke 2005; Frank *et al.* 2005) have shown relationships between specific urban form characteristics (e.g., land use mix, residential density) and both activity and health correlates.

2. Methods

Moudon and Lee (2003) have suggested a behavior model of environments to focus the understanding of the relationship between the built environment and walking or cycling activity. For trips, this model consists of three components: (1) origin and destination, (2) route characteristics, and (3) characteristics of the area in which the trip takes place. In order to fully understand and measure the effect of the environment on walking or cycling trips, each of these components must be operationalized and measured. A few examples of the many possible measures in these components include: area and proportion of different land uses, parcel sizes, residential densities, street lengths, number of bus stops, and street sinuosity. Understanding the built environment in this way requires detailed, feature-level data and specialized routines for processing these data. GIS provides the data, measurement, and analytical frameworks to measure these types of variables.

We have developed an ArcView GIS 3.x extension for measuring over formal 200 variables based on locations of interest. Our extension, the WBC Analyst ("Walkable-Bikeable Communities"), calculates a number of quantities describing the structure of the urban environment. Originally written for a project to estimate the walkability and bikeability of neighborhoods (CDC SIP 18-01[1]), the extension can be used for any project requiring detailed data representing the area around a single point or a series of points of interest, assuming source data sets meet format requirements.

In addition to the GIS component, we performed an extensive survey of households in the Seattle area and associated results of the survey with measures obtained by use of the GIS tool.

2.1 Data sources and preparation

The WBC Analyst takes advantage of the plethora of GIS data sources available for the City of Seattle and King County, Washington State. The extension was written specifically for these data sets, which have particular data structures; however, with some editing of the underlying Avenue code and necessary modification of some data structures, the extension could be made to work for any location, assuming the existence of necessary supporting data sets.

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[1] CDC Description of the WBC Project, *Assessing Communities' "Walkability" and "Bikeability"*

"Americans may choose not to walk or bicycle in their neighborhoods because of environmental conditions not conducive to these activities. Conditions such as designated walking trails, well-lighted streets, and on-road bicycle lanes may help promote participation. Physical activity specialists are developing tools for assessing whether neighborhoods are walkable and bikeable. The researchers are reviewing existing instruments for environmental auditing and have surveyed 600 residents (in Seattle's King County) by telephone about their attitudes and behaviors toward walking and bicycling. Residents' perspectives and habits are being compared with objective characteristics of their neighborhoods. Using the results, the researchers will structure new instruments for auditing environments' support for walking and bicycling as regular activities."

2.1.1 *Parcel data*

Because the composition and configuration of land use is an important driver of behavior, the most important data set for the WBC Analyst is the parcel polygon theme. Due to the disparate nature of original data sources, constructing a single parcel theme with all required land use values took substantial time and effort on the part of one of our analysts. The parcel data set was specially conflated for the WBC project based on several sources, including King County parcel and building data. Random field checking was a necessary data verification step. Because any single parcel can contain multiple land uses, the attribute table was constructed to contain a binary field for the existence of each individual land use. In the most extreme case, for example, a single parcel representing a shopping mall may have retail, service, restaurant, grocery, convenience store, post office, health club, and other land uses. By convention, we encoded these in numeric fields with three-character names. Using this convention, the scripts can easily identify all land uses for every parcel in the data set. Not all numerically formatted fields with three-character necessarily represent land uses, so we included a control to mark which field actually represent valid land uses (Figure 1). Any fields that do not represent land use can be unchecked and will be excluded from any further land use analyses.

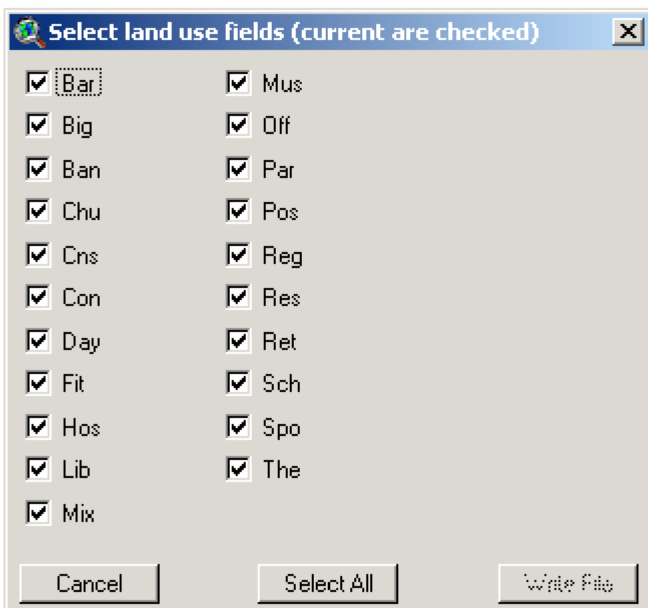

Figure 1: Generalized Land Use Specification Dialog

In addition to general land use fields, some land uses are key destinations which may have a greater draw for walking or cycling. These are specified in a similar way as the general land use fields. An additional functionality is the specification of different *combinations* of key land uses (e.g., restaurant, bar, grocery, and theater). Each different combination of key land uses can be saved for use in Neighborhood Center (NC) Analysis (Figure 2).

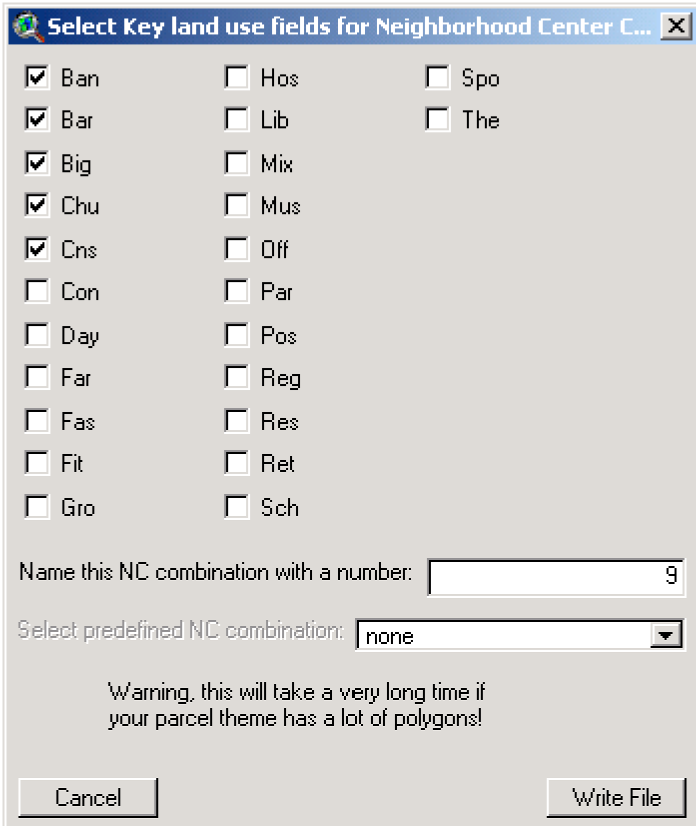

Figure 2: Key Land Use Specification Dialog

The dialog is also used to view or edit NC combinations that have been previously defined. Values for NC key land uses are written back to the parcel attribute table in binary fields named for each NC combination.

2.1.2 Locations of interest

The other major data set consists of point locations of interest (in the case of the WBC Project, these represent individual households and were generated by geocoding addresses against the King County Street Network data set). For analysis of other point processes or features, these could represent any single XY location, such as a business, workplace, accident site, or transit stop. The final sample of 608 households was stored as a single point shapefile including an identifier field to allow relational links with the survey data.

2.1.3 Buffers

Most of the metrics generated by the WBC Analyst are summaries of urban form characteristics within a user-specified distance of the locations of interest. Therefore, one of the first data preparation steps is to create buffers around each location of interest. Figure 4 shows the two interfaces for creating buffers. The user specifies a buffer distance in both cases. For the Euclidean buffers, only a distance value needs to be specified; for the network buffers, both a buffer distance and a network theme (typically streets) require specification in order to create buffers.

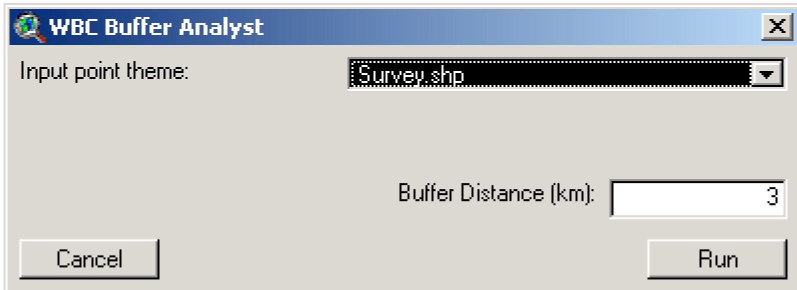

Figure 3: Euclidean Buffer Generator Dialog

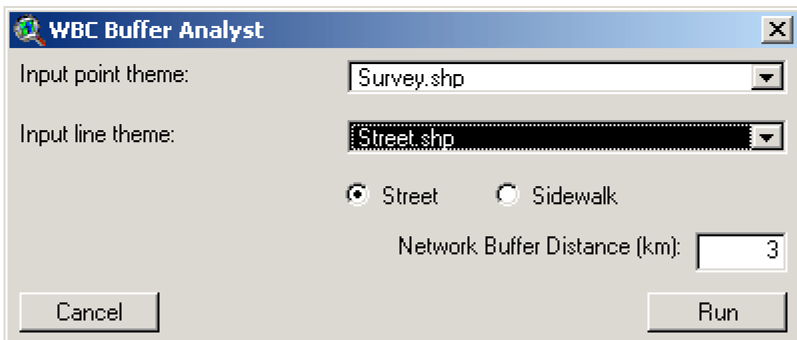

Figure 4: Network Buffer Generator Dialog

Both Euclidean and network buffers are created for each location of interest. Buffers are stored in separate shapefiles for each location of interest and buffer distance and type. Storing buffers as individual shapefiles provides much faster access than storing buffers for several locations of interest within the same shapefile. Figure 5 shows a 3 km Euclidean and network buffer for a single location of interest. Because of network distance constraints, network buffers are always smaller than Euclidean buffers. This can be an important consideration if the mode of transportation is limited to formal pathways such as roads or sidewalks.

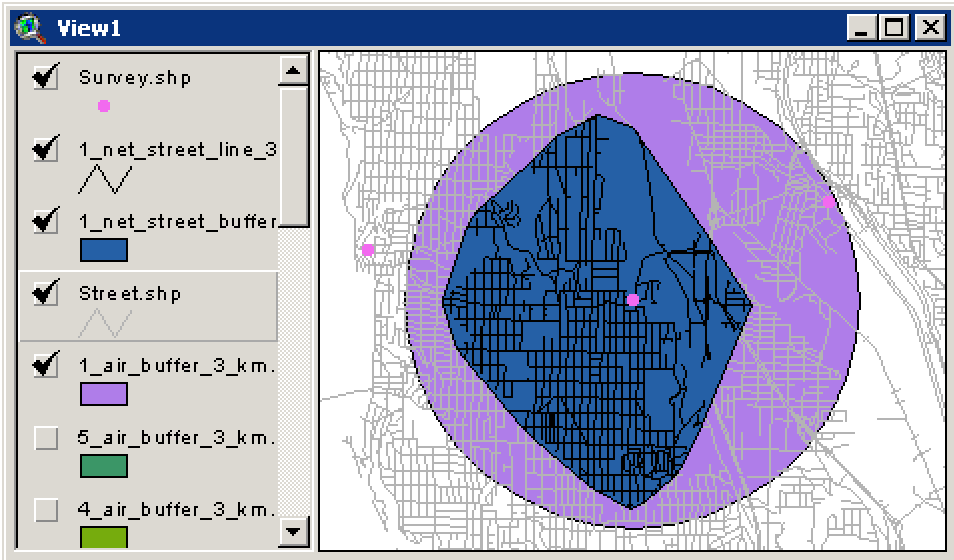

Figure 5: Example Euclidean (lavender) and Network Buffers (blue) for a Single Location of Interest.

2.1.4 Other data sources

For tabulation of other urban environmental elements we also used vector data sets representing bike lanes, street blocks, bus stops, crosswalks, street intersections, parks, sidewalks, streets, street lanes with speed limits, traffic signals, traffic volumes, and regional trails, and a single raster data set representing slope.

2.2 Analytical components

The WBC Analyst extension has three basic modules: (1) land use proximity analysis, (2) land use buffer analysis, and (3) neighborhood center cluster analysis. Each component has different functionality and results, providing data for different conceptualizations of urban form around the location of interest.

The land use proximity analysis module specifically identifies and summarizes individual destination land uses within the user-defined proximity to locations of interest (buffer). The land use buffer analysis module calculates summary measures of classes of land uses and other features within the buffer. The neighborhood center cluster analysis module creates and analyzes spatially aggregated parcels containing user-defined combinations of land uses, using both proximity and buffer measures.

2.2.1 Land use proximity analysis

The WBC Proximity Analyst is used to quantify the proximity of each location of interest to each defined land use. Proximity is calculated for a user-specified distance, in both Euclidean and network measurement frameworks. The WBC Proximity Analyst has a simple interface, which only requires the specification of the household point theme, the parcel polygon theme, a network tolerance value, the network source type, and the buffer distance (Figure 6).

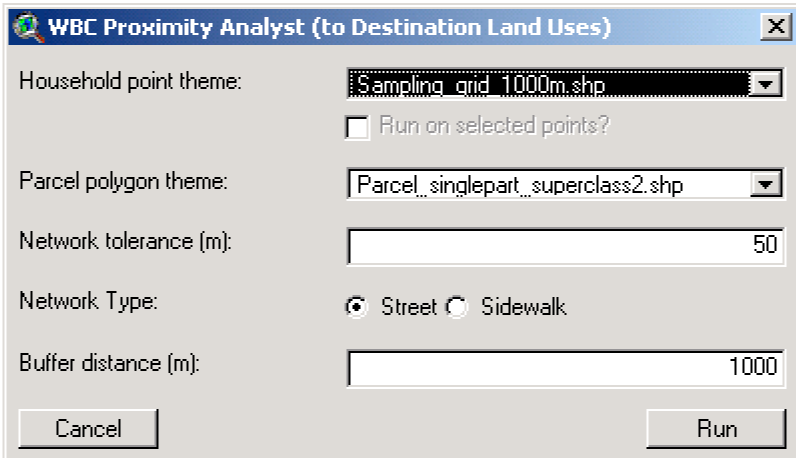

Figure 6: The WBC Proximity Analyst Dialog

The WBC Proximity Analyst extracts all parcels within the buffer around each location of interest and calculates measures for each different land use, as encoded in the parcel data set. These measures include (1) the raw count of parcels with each land use, (2) the mean proximity to all parcels of each destination land use type, (3) the distance to the closest parcel with each given land use, and (4) the unique parcel identifier of the closest parcel with the given land use. Summary measures are obtained for both Euclidean and network buffer polygons, and proximity measures are obtained for and for both Euclidean and network distances. The ratio of network to Euclidean distances is also calculated for the closest parcel of each land use. For this, as well as all other analyses, output tables contain the unique location of interest identifier, allowing relational operations between the locations of interest and the summary tables. Figure 7 shows the Identify Results dialog for a single output record representing the land uses within a 1 km Euclidean buffer around a single location of interest. Each land use has a value for the four measurements described above. The 10-character limit for field names in the dBase IV standard necessitated a complicated nomenclature for output fields (e.g., **caBan** = **c**ount, **a**irline, of **Ban**ks; **pmaBan** = **p**roximity, **m**ean, **a**irline, of **Ban**ks; **pcaBan** = **p**roximity, **c**losest, **a**irline **Ban**ks; **paBanwbc** = **p**arcel identifier, **a**irline, of closest parcel containing a **Ban**k).

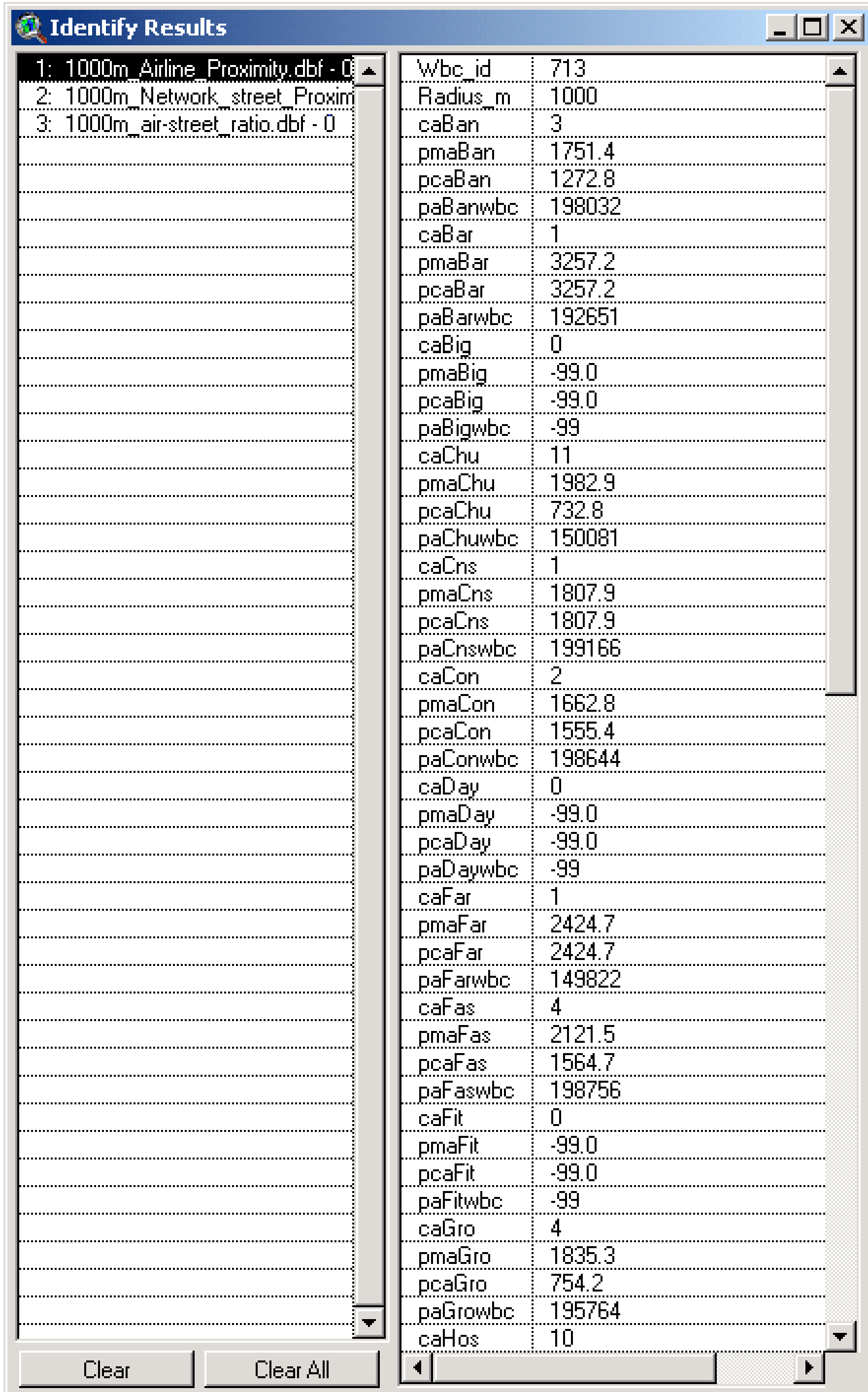

Figure 7: Example of a single Land Use Proximity output record

The measurements obtained from the WBC Proximity Analyst are not complicated; in fact, these could very easily be obtained by standard methods built into the GIS. What makes this a valuable tool is its ability to automatically detect land use fields in the parcel attribute table, and to automate the summary process for an entire data set representing numerous locations of interest. Not only does this save a tremendous amount of time, it reduces the possibility of user error, and places the output in a single compact table containing all measures for each location of interest.

2.2.2 Land use buffer analysis

Whereas the WBC Proximity Analyst specifically identifies and summarizes *individual* destination land uses within proximity to locations of interest, the WBC Land Use Buffer Analysis calculates measures of *classes* of land uses as well as other landscape features within the user-specified buffer distance. A characteristic of the King County parcel data set is a "description" field, which identifies the major land use of each parcel. Over 120 unique descriptions exist, many of which represent functional equivalents. For example, the multifamily land use encompasses the parcel descriptions "Apartment," "Apartment (co-op)," "Apartment (mixed use)," "Apartment (subsidized)," "Condominium (mixed use", "Condominium (office), "Condominium (residential)," and "Retirement facility." In an intermediate step, the user defines land use "superclasses," and associates each description to a superclass. Each member of the multifamily functional group may be encoded with a superclass value of "MF" for further processing. Figure 8 shows the dialog used for land use classification for buffer analysis. The dialog contains controls for defining or listing superclasses and associating superclasses with specific land use descriptors from the parcel attribute table

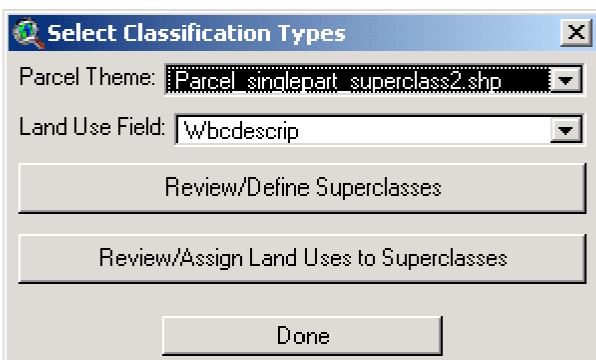

Figure 8: Land Use Classification Dialog

Figure 9 shows the dialog for listing or modifying the list of superclasses. In this example, eight superclasses are shown, but the number and type of superclasses is entirely user-controlled.

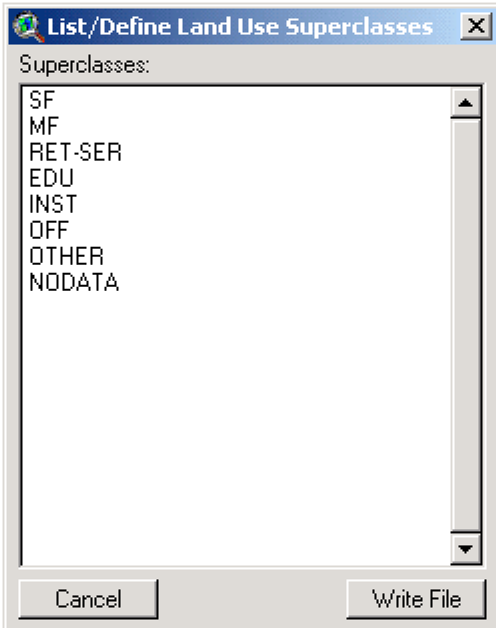

Figure 9: Land Use Superclass Definition Dialog

Once superclasses have been defined, these are relationally associated with the individual land use descriptions. The script for this summarizes unique values from the land use field and places these in a dialog that is created on the fly from the contents of the parcel attribute table. Figure 10 shows how each individual land use from the parcel table is associated with its superclass value. A dropdown combobox allows the user to select a superclass to be associated with each land use description. The superclass values are then written to the parcel attribute table, so each parcel will be tagged with the superclass to which it belongs. In this example, the land use descriptor "4-Plex" is associated with the "residential" superclass, and the land use descriptor "Auto Showroom and Lot" is associated with the "commercial" superclass. (Note the superclasses selected for association in Figure 9 are different from those defined in Figure 8.)

Figure 10: Associating Superclasses with Land Use Descriptors

After the parcel attribute table has been prepared to contain the superclass value, summary characteristics are generated for the network and Euclidean buffers around each location of interest for each specified urban form data set. Paired checkboxes and comboboxes on the interface allow the user to select which urban form data sets to summarize (Figure 11: Buffer Characteristics Specification Dialog). To reduce confusion, only when a theme's checkbox is checked does the combobox for the data source appear in the dialog.

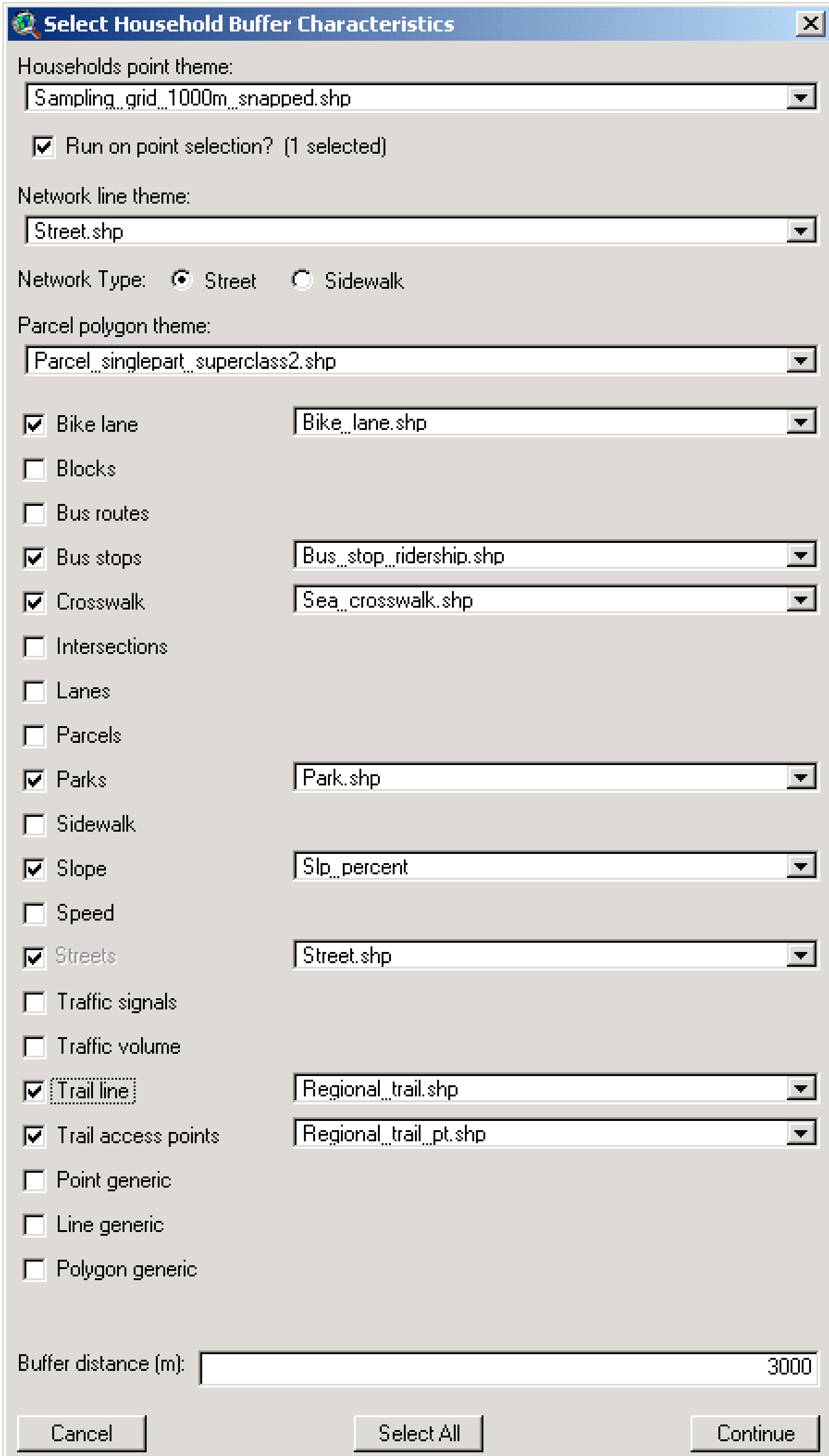

Figure 11: Buffer Characteristics Specification Dialog

Land use buffer characteristics values for parcels are quite similar to the basic proximity values, but are based on area of overlap rather than on distance calculations. Also, rather than calculating metrics only for individual land uses as defined in the parcel attribute table, characteristics are also gathered for superclasses. For the parcel data, each superclass within the location of interest buffer is summarized (e.g., count, total area, percent by count and area).

For data sets other than parcels, simple geometric measures of overlap are calculated. For point data sets, the count of point features is calculated. For line and polygon features, the total length and area overlapping the buffer is calculated, respectively, for both simple overlap and clipped edges. In addition to the predefined themes listed in the dialog, we have added generic point, line, and polygon themes in the analysis; for these features, geometric measures of overlap are calculated in the same way as for hard-coded data sets.

Depending on the type of feature, measures beyond simple geometric overlap are obtained, such as bus ridership (points), percents of different street types or maximum lane speed (lines), area of slope greater than 8% (raster), or type of park (polygon).

Output from this process is placed into a table with one record for each location of interest, identified by the unique ID number for relational operations with the location of interest attribute table.

2.2.3 Neighborhood center cluster analysis

The last major function of the WBC Analyst is to create “Neighborhood Center Clusters.” These Neighborhood Centers (NCs) are spatially aggregated groups of parcels with a predefined land use composition. The NCs are defined by both spatial and attribute properties. Spatially, NCs consist of several parcel polygons that are within a user-specified distance of each other; in terms attribute structure, each NC must consist of a specific number and combination of land uses. If a group of parcels matches both the spatial and the attribute criteria, a polygon is created for later analysis.

The first step in creating NCs is to identify the key land uses for that type of NC land use mix (Figure 2). Because NCs must consist of parcels that are within a user-specified distance of each other, buffers must be generated around key land use parcels. The interface for creating the buffers is shown in Figure 12. The buffer maker automatically selects only those parcels with key land uses.

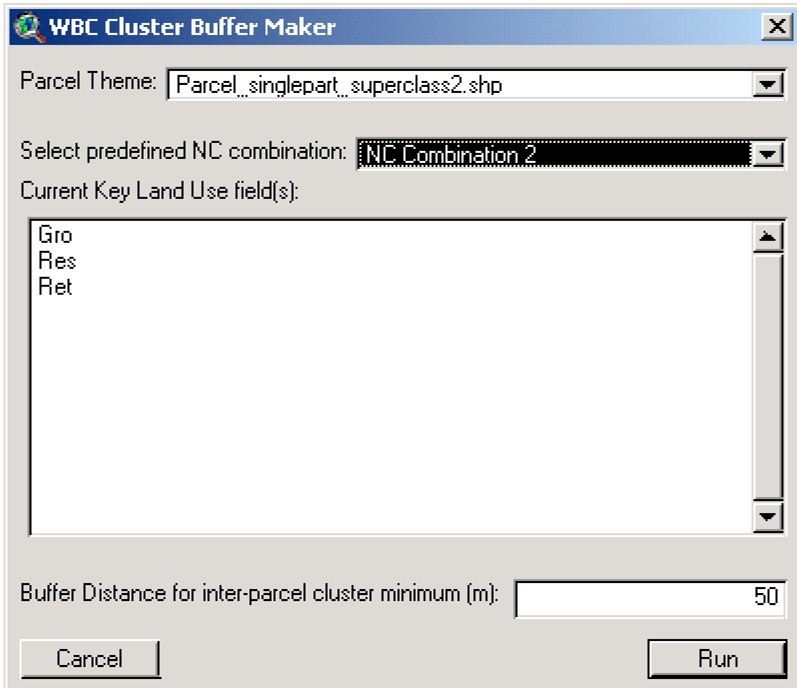

Figure 12: NC Buffer Dialog

For our research questions we created a number of different NC combinations, representing clusters of land uses that serve specific groups of functions, e.g., educational, sports-related, retail/restaurant, office, mixed. However, this interface allows the user to define NC land uses based on any combination of existing land uses.

Buffers are created for each key land use parcel and then dissolved (Figure 13 and Figure 14). Each dissolved buffer polygon contains a group of parcels representing a potential NC, provided the parcels match the selection criteria.

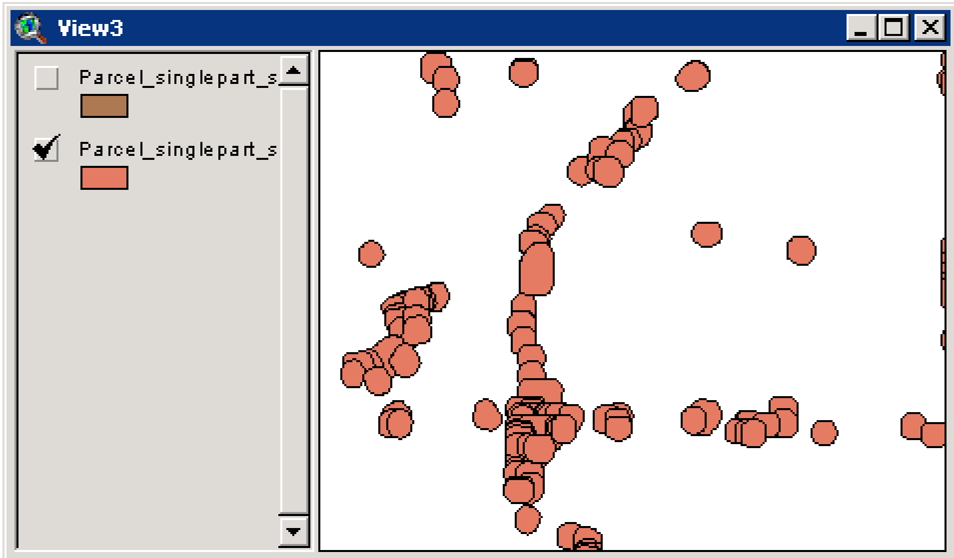

Figure 13: NC Buffers

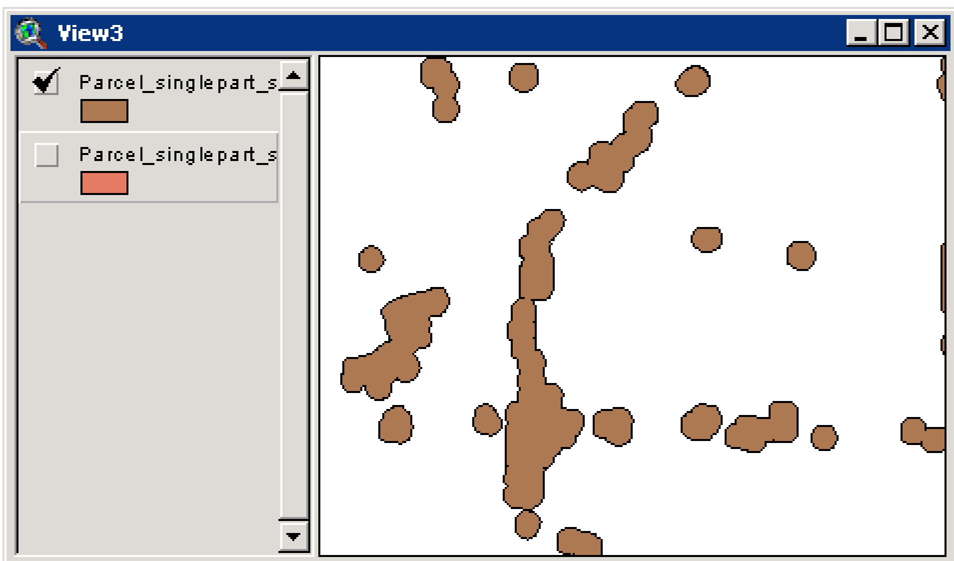

Figure 14: Dissolved NC Buffers

After the buffers are created and dissolved, the user specifies the properties defining an NC (Figure 15). There is a choice of several different attribute-level criteria for an NC:

1. <u>One of each key land use</u>; in the example case, if the parcels within the dissolved buffer contain at least a single grocery store, a single restaurant, and a single retail store, then an NC will be created. In the simplest scenario, a single parcel may have all three key land uses, which would create an NC composed of a single parcel.

2. <u>One of each key land use and a minimum number of key land use parcels</u>; this expands the first criterion by requiring a minimum number of parcel polygons containing key land uses. Here, the requirement is to have several parcels, the number of required parcels within the NC is user-specified.
3. <u>One key land use and a minimum number of key land use parcels</u>; in this case, an NC needs to contain only a single key land use parcel, but the NC also needs to contain enough parcels containing key land uses to meet the user's specification. Using the example definition, an NC may contain a single grocery store parcel plus several other retail parcels, but need not necessarily contain a restaurant parcel. Alternatively under this scenario, an NC could be created that simply contained the minimum number of restaurant parcels.
4. <u>Minimum number of unique key land uses and a minimum number of key land use parcels</u>; this is potentially the most complex and restrictive criterion. Under this scenario, the NC must contain an adequate diversity of key land uses *and* a minimum number of key land use parcels.

If the combination of parcels within a single dissolved buffer meets the user-specified criteria for an NC, a minimum convex polygon (MCP, also known as a convex hull polygon) is created based on the polygon geometry of the constituent parcel polygons.

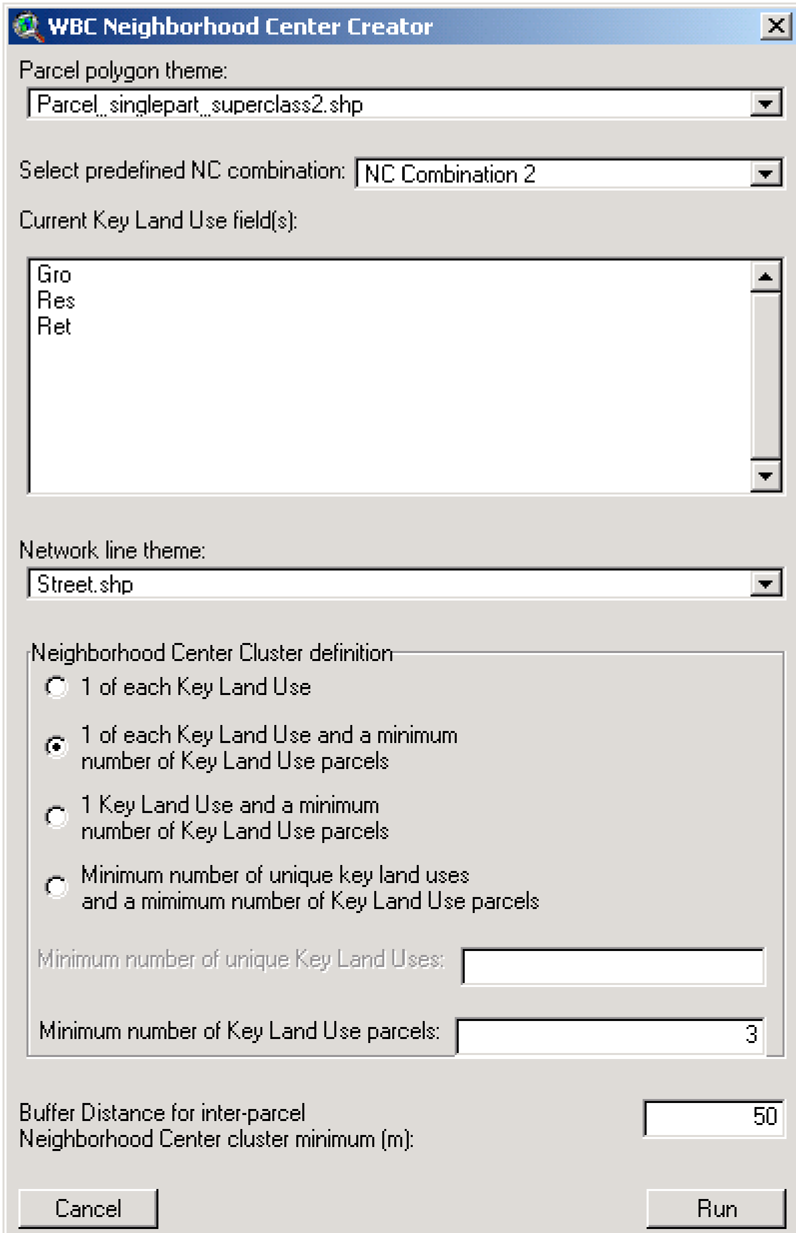

Figure 15: NC Creator Dialog

Parcels within dissolved buffers containing adequate numbers and land use mix are used to generate NC MCPs, as shown in Figure 16. Note that several potential dissolved buffers do not contain NCs, as they did not meet the definition criteria.

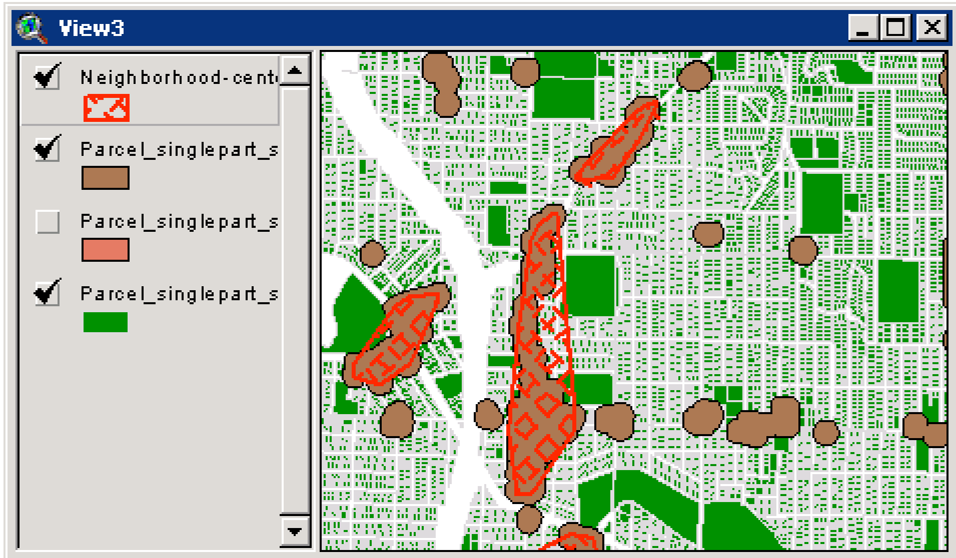

Figure 16: Neighborhood Center Polygons

Once the NCs are created, it is possible to perform the same proximity and buffer measures on the NCs as on the locations of interest. Like the locations of interest, the WBC Analyst contains tools for summarizing the mix of land uses within a user-specified distance, as well as to identify the number and proximity of each specific land use in the parcel database. The interfaces for NC analyses are nearly identical to those for locations of interest (Figure 17 and Figure 18), as are the calculations.

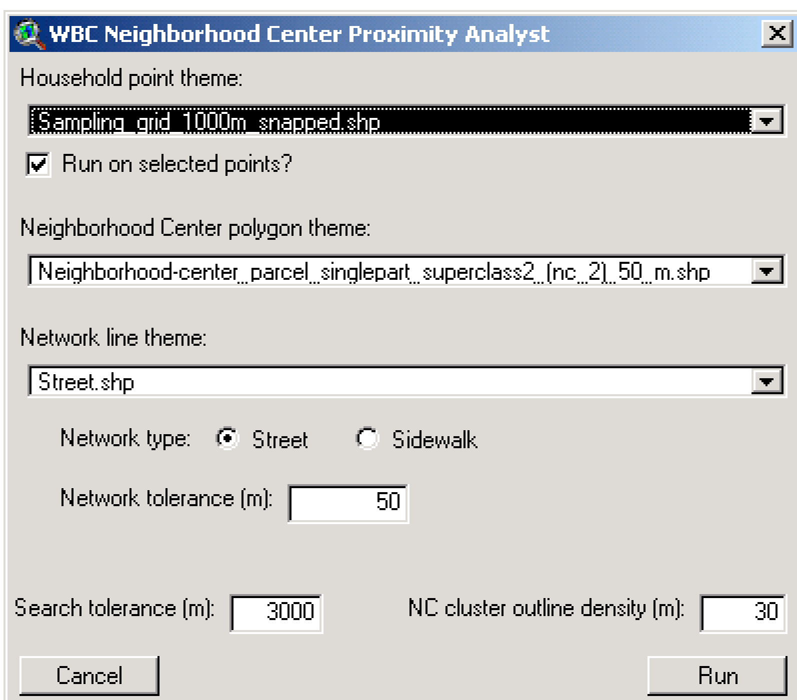

Figure 17: The WBC Neighborhood Center Proximity Analyst Dialog

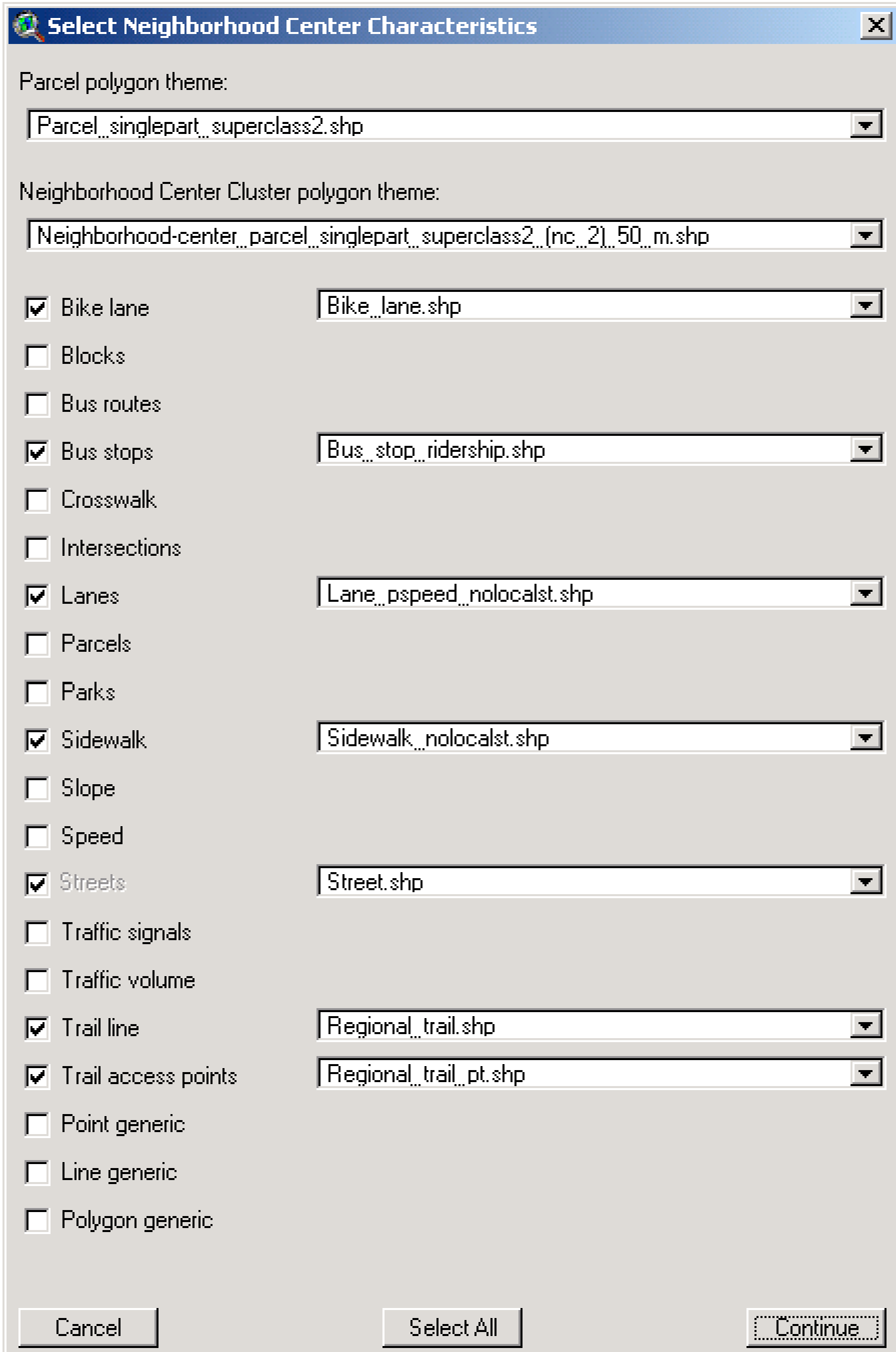

Figure 18: The WBC Neighborhood Center Buffer Dialog

2.3 *Telephone Survey*

In order to associate neighborhood urban form characteristics with behavior, we performed an extensive telephone survey of residents in urbanized King County. We obtained a final sample of 608 randomly selected able-bodied adult respondents (a response rate of 35.5%). We used a novel spatial sampling technique to obtain a sample representative of the population under investigation that also captured variability in environment and socio-demographic characteristics (Lee, Moudon, and Courbois 2005). This methodology gives more statistical power and greater generalizability with a smaller sample size than with a typical randomized within-neighborhood or within-census polygon sampling.

The telephone survey, which took approximately 25 minutes per subject, included questions on physical activity (physical ability for walking and cycling, amount of walking or cycling, and walking and cycling destinations) and socio-demography (use of transit services, perceptions of various land uses or services within the neighborhood, amount of physical activity, residential/household characteristics, race/ethnicity, income, employment status, education level, height and weight, and general health status). The survey instrument used existing questions from a number of previously validated telephone surveys, with the addition of other questions specifically targeting walking and cycling behavior.

2.4 Statistical Analysis

Statistical analyses were performed in order to establish an association between urban form characteristics and survey results. We used a multinomial logit model to estimate the likelihood of walking sufficiently or moderately relative to not walking. In one model we estimated the likelihood of walking versus the survey variables; in an expanded model we also included environmental variables obtained with the WBC Analyst. We also compared cycling versus not cycling (from the survey) to socio-demographic variables (also from the survey) and objective environmental characteristics (from the WBC Analyst).

The destination land uses measured as part of the environmental characteristics included grocery stores, fast food restaurants, pubs/bars/taverns, big box retail stores, banks, churches, neighborhood/community shopping centers, convenience stores, day care centers, fitness centers, medical/dental/hospital facilities, libraries, mixed use, art galleries/museums, offices, post offices, regional shopping centers, full-service restaurants, retail stores, schools, sports facilities, movie theaters, trails, and parks.

3. Results/Discussion

The purpose of this paper is to describe in detail the methodology at work in the WBC Analyst rather than its specific application within the WBC project. However, I also present some results from the larger study. For more detailed results, for the cycling study, see Moudon *et al.* (2005). Other results are forthcoming, pending review.

Using socio-demographic factors from the survey alone, we were able to explain approximately 35% of the variation in walking and bicycling. Adding the environmental variables increased the R^2 value to 0.47.

In the base model, age, education, neighborhood social environment, and attitude toward traffic and environmental quality were significant influences in the decision to walk. In the extended model, the presence of several different land uses were found to significantly increase probability of self-report of sufficient or moderate walking versus not walking, including grocery stores, eating/drinking establishments, schools ($p < 0.05$). Other significant variables include more sidewalks, smaller block sizes, higher residential density, and *greater* distance to office land use.

Our initial work in this area shows that environmental influences are strongly associated with walking sufficiently or moderately. Destinations that are used frequently, such as banks, retail stores, grocery stores, restaurants, pubs, schools are significantly associated with greater levels of walking. Proximity to several NCs (e.g., [grocery + retail + restaurant]; [schools + churches]) were positively associated with walking. While overall land use mix (overall percent of land uses within a walking distance buffer) did not have an effect on walking, the proximity to agglomerations of these land uses did. This indicates people may be more inclined to walk to areas of clustered, rather than dispersed, mixed use.

Some land uses, such as grocery stores, restaurants, and banks, are significantly associated with walking in both the limited (survey only) model as well as the model containing environmental variables.

Surprisingly, proximity of parks and trails was not strongly correlated with walking in our study. Apparently destination land uses such as those listed above are stronger draws for walking. This may be a result of the relatively large distance between households and walking trails in the region. And while proximity to parks may not increase the total amount of walking, it may still increase the probability of use of these parks and trails. However, for cycling, presence of trails in proximity to household location was a significant factor (Moudon *et al.* 2005). Surprisingly, other route-related variables (number of lanes, traffic speed, traffic volume, slope, and block size) were found to be insignificantly related to cycling.

3.1 Limitations

There are several limitations to the use of this method. Limitations in data, software, and spatio-temporal conditions of the sample base reduce the study's internal and external validity.

3.1.1 Data Limitations

The main data set used for the WBC Analyst (parcels) required conflation from several different data sources. As noted above, this was a fairly time-consuming and complicated task, and most likely introduced some error, but was nevertheless a requirement for the type of data modeling we used. Other data sets were those readily available to the Urban Form Lab through data sharing agreements between the University of Washington and local governments. While data from other locales may be used in the tool, these data will almost certainly need substantial data massaging in order to meet the standard for which this tool was developed. We are considering efforts either to make the tool more generic or to build a data verification tool that would report the discrepancies between the WBC Analyst's expected data structures and users' existing data structures.

Some of the results we obtained may be biased due to incomplete data sets. For example, based on *ad hoc* spot checking, the sidewalk line data sets tended to be more complete within the Seattle City Limits than outside. For cases such as this, we do not necessarily know the difference between sidewalks not actually being present or simply not being present in the database. As the quality and completeness of available data sets increases, these types of issues will become fewer.

3.1.2 Tool Limitations

The tool was written specifically for ArcView GIS 3.x, which, at the time, was the most logical choice of software; our team was well-versed in the use of ArcView GIS but not experienced with ArcInfo Workstation. ArcGIS version 8 and 9.0 both lacked network analysis functionality, a core dependency for many of our routines. Furthermore, ArcView GIS 3.x provides a robust, compiled, object-oriented API (Avenue) which generally decreases both development and run times over ArcInfo AML.

Further developments of GIS-based tools will be done on the ArcGIS 9.1+ platform, to incorporate additional functionality, such as multi-modal network modeling, to appeal to the growing user base for this software, and to take advantage of Windows interoperability.

3.1.3 Study Limitations

The spatial limit of our sampling frame limits the generalizability of the results. Further study in other locations is necessary in order to characterize general patterns of the relationship between urban form and physical activity. This tool provides a framework for promoting this line of inquiry.

For the overall WBC study, there were a few strong limitations. Our study was cross-sectional, obtaining measurements for urban form characteristics and survey results at a single point in time. Because of the nature of residency, it is not possible to determine causation; do people with an inclination to walk move to neighborhoods with a specific type of urban form, or is it the form of the neighborhood that drives propensity for walking?

4. *Conclusions*

The three D's of walking – Destination, Distance, and Density – emerge to be the major drivers of walking within one's household neighborhood. Enough specific destinations (most notably a grocery store or market), within a reasonable walking distance (hence density) appear to act as stimulators for walking. Route characteristics, such as the size of street-blocks, and length of sidewalks, are important, but to a lesser degree. Proximity to trails emerges as the strongest single environmental driver for cycling.

Unlike studies utilizing aggregated data from neighborhood or census boundaries, our method focuses on atomically measurable phenomena, which can be directly translated into quantitative policy recommendations and best practices for design.

Our work shows that using the traditional interview survey, coupled with spatial sampling and automated environmental data extraction can be a powerful combination in understanding the relationship between physical activity and characteristics of the urban environment.

The study of the relationship between public health and characteristics of the built environment is in its infancy, but tools like the WBC Analyst should allow greater advancement in this field.

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6. *Bibliography*

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