Model Objective:

The objective of the **Urban Tree Risk Index** model (UTRI) is to prioritize street segments of a community for more detailed (comprehensive or intense) risk assessment, mitigation, and management. In addition, the UTRI and resulting urban tree risk management is a critical component in the Vegetation Risk Management Plan.

Model Overview:

CARPDC has developed a relatively simple GIS approach to rank areas of the community for their likely risk to infrastructure and human life in the event of a natural disaster (e.g. hurricanes, ice storms, straight-line winds) based on the publication **Urban Tree Risk Management: A Community Guide to Program Design**[1].

The **Urban Tree Risk Management** guide outlines a process for prioritizing, assessing, and mitigating tree risk in urban areas. Its principal underlying concept is the "tree risk zone" that guides urban forest managers to those areas of greatest concern when resources are limited. The CARPDC **Urban Tree Risk Index** (UTRI) tool is used to identify and prioritize street segments as "tree risk zones" that provide the prioritization framework for planning, assessment, mitigation, and response to natural disasters. The UTRI is the basic driver for the Vegetative Risk Management Plan which includes collaborative strategies, the tree risk map, street segment (tree risk zone) field verification forms to guide detailed assessment, pre- and post-disaster mitigation, debris estimation, and disaster response.

The methodology (GIS model) and resulting ranking is a "springboard" for state, regional and local collaboration of community leaders, emergency managers, regional and local planners, community staff, and the urban forestry profession.

The UTRI model supports the "Collection Strategy" prioritization outlined in the Public Assistance Debris Management Guide (FEMA 325, July 2007).

In addition, UTRI supports key concepts of the National Disaster Recovery Framework[2]:

- local government has the primary role of planning and managing all aspects of the community's recovery,
- the ability of a community to accelerate the recovery process "beginning" with its efforts in pre-disaster preparedness, mitigation and recovery capacity building,
- an impacted community assumes the leadership in developing recovery priorities and activities that are realistic, well-planned and clearly communicated.

GIS Approach:

As developed within GIS the **Urban Tree Risk Index** (UTRI) becomes a powerful tool at the state and regional level for long-term disaster planning, and at the regional and local levels for planning, mitigation, response, and recovery.

Tree risk is associated with: targets (infrastructure or human), trees and their structural characteristics, and an evaluation of failure probability. UTRI does not look at individual trees, but at the spatial distribution of high priority but vulnerable community infrastructure, human population, and tree distribution (based on tree canopy) to guide planning, prioritized assessment, and mitigation by urban forest and emergency managers.

UTRI uses a street segment as the smallest risk zone element for analysis. A street segment is the portion of a street between two intersections, or from an intersection to the end of that street. Within any area being analyzed, the street segment length may vary considerably. However, these street segments are typically shorter and more uniform (i.e. less variability) in urbanized areas where disaster effects are greatest for people and infrastructure (i.e. street network density is typically related to non-street infrastructure which is related to

[1] Jill D. Pokorny (Coordinating Author), USDA Forest Service, Northeastern Area, State and Private Forestry, 1992 Folwell Ave, St. Paul, MN 55108, NA-TP-03-03, 2003, 194 pages.

[2] National Disaster Recovery Framework: Strengthening Disaster Recovery for the Nation, Department of Homeland Security (DHS), Federal Emergency Management Agency (FEMA), Washington DC, September 2011, 116 pages.

population density during the daytime and/or nighttime; the assumption here is that as the built environment intensifies, then there are probably more people).

The UTRI implementation of "tree risk zones" helps:

1. develop Debris Management Plans and Hazard Mitigation Plans
2. identify areas for block-level or individual tree risk assessment
3. guide local risk management and pre-storm mitigation (pruning and removal)
4. create non-threatening tree planting projects (proper species and site evaluation)
5. stratify a debris estimation sample
6. prioritize disaster response

<u>GIS Data: Sources:</u>

The most accurate and current GIS data should be obtained. Possible sources include:

- Municipal planning and GIS agencies — Examples: facilities, boundaries
- Municipal urban forest management — Examples: tree canopy, tree risk management
- County EM and planning agencies — Examples: facilities, imagery
- Regional planning agencies — Examples: transportation, imagery
- State agencies (EM, DOT) — Examples: transportation, facilities
- Department of Homeland Security — Examples: HSIP Gold including facilities, population
- US Census — Examples: population, other TIGER lines
- USDA Farm Service Agency (FSA) — Examples: NAIP 1 meter imagery
- US DOI, Geological Survey — Examples: MRLC 30 meter tree canopy

<u>GIS Data: Assembly:</u>

For the area of interest (AOI), the GIS data needed to develop the tree risk rating and calculate the priority index that supports the Vegetation Risk Management Plan includes the following spatial layers:

1. county and municipal boundaries
2. street and highway infrastructure
3. community infrastructure most important during disaster response (e.g. hospitals, EM, police, fire, water supply, and water treatment)
4. population density
5. tree canopy

Within the GIS methodology developed, each of these UTRI components is converted to a GIS raster layer(s) with a rating that reflects component importance or level of concern. The resolution of the rating can vary depending on the availability of GIS data. In the Autauga and Elmore County (Alabama) prototypes, 30 meter pixels were used.

The UTRI represents the important relationships that exist among these GIS layers relative to disaster planning, response, and recovery (short-term and long-term).

For example, storm damaged trees can:

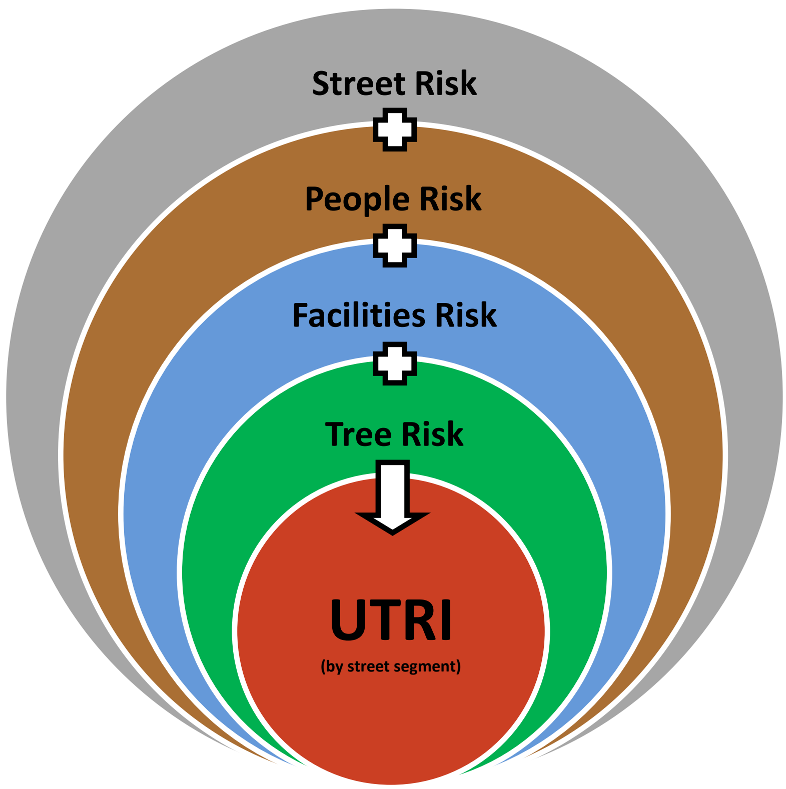
- directly injure or damage…
  - people
  - facilities (e.g. buildings, bridges)
- block emergency access to…
  - injured people
  - emergency facilities (e.g. EM, public safety, hospitals, shelters)

- disrupt…
    - communication
    - energy
    - water supply and treatment
    - food supply
- affect…
    - debris generation (i.e. quantity)
    - debris handling (i.e. number and locations of debris sites)
    - the "flow" of environmental services from tree canopy (i.e. temporary or permanent losses/reductions in stormwater, shade (energy), PM10 capture, and visual or noise buffers)

<u>GIS Data: Preparation:</u>

Assignment of priority ratings within each layer are dependent on the layers attribute properties and the regional/local disaster perspective. The scale of the UTRI analysis (that is, the area of interest) has a bearing on assignment of individual layer ratings that are "summed" into the final UTRI risk index. For example, if developing a UTRI for a municipality, regional health care and the transportation corridors to reach those regional care facilities may not be as important if the community has local facilities (i.e. emergency care options) of sufficient size and capability for the planned event.

<u>GIS Data Overlay Relationships:</u>



Objective: Users will step through the model, format input data layers from multiple sources, and create five raster layers that can be summed to create the UTRI. The final UTRI is then assigned back to the street segment layer for field verification, urban forest risk management, disaster planning, debris stratification, and/or response prioritization.

UTRI GIS Model Worksheet & Tool Description

Folder: ____

Project Name: ___________________________________ Geodatabase: ___________________________________ Coordinate System: ____ Resolution: _____ meters

Process Step	Data Source	GIS[3]/Model Processing[4]	Model Tools	Data Layer(s)[5]	Input Attribute	Output Attribute	Assignment or Reclass	Model Notes	GIS Processing Notes (As Built)
1 Assemble data layers needed (see **Data Source** column for steps ❶-❿). Create a folder & subfolders for the project; for example: …\UTRI2012Elmore …\UTRI2012Elmore\SourceData …\UTRI2012Elmore\Maps …\UTRI2012Elmore\Documents).	See below in this column and **Notes** column links.	NA	NA	NA	NA	NA	NA	http://www.census.gov http://www.mrlc.gov https://www.hifldwg.org Other local/regional/state sources	Input Layers: Output Layers: Other Comments:
2 Create an ArcMap personal/file geodatabase and map document (i.e. project) in the project "root" folder from the previous step. Set the default geodatabase.	NA	ArcCatalog ▪ Create/select folder ***File=>New Personal Geodatabase*** *ProjectNameDate* ArcMap ***File New…*** ***Dialog=>Default geodatabase***	NA	NA	NA	NA	NA	The geodatabase is an excellent file/layer organizational tool and may also function as process documentation. It should hold all intermediate layers used in the processing as well as the final vector and raster layers. An example *ProjectNameDate* might be: *UTRI2012Elmore.mdb* The original supporting data (e.g. NLCD or Census) does not have to be placed into the geodatabase. Set projection and datum for the geodatabase and then make it the 'default' geodatabase when you create your map document (i.e. the mxd; the 'project'). **Note:** Users may opt to use ArcGIS shapefiles and stand-alone raster files if desired. Layer name may be used as the shapefile and raster file names.	Input Layers: Output Layers: Other Comments:
3 Create project boundary; i.e. the area of interest (AOI)	2010 Census TIGER Lines - Geographic Areas=>Counties (and equivalent)	Data Download ▪ Census data or other UTRI Model ▪ Select feature (AOI) ▪ Extract AOI feature ▪ Buffer to 1k or desired distance ▪ Project to project coordinates ArcMap ***TB=>Select Feature (e.g. County)*** ***RC=>Data=>Export Data*** ArcToolbox ***Analysis Tools=>Proximity=>Buffer***	02_UTRI-AOI	AOI_Region AOI_County AOI_City AOI_Other	NA	NA	NA	Source: http://www.census.gov/cgi-bin/geo/shapefiles2010/main. Use UTRI model tool or ArcToolbox. This step may include multiple levels (e.g. county, municipality, neighborhood). Intermediate layer names should lead to or reflect the final layer to be used by UTRI; e.g. *AOI_CountyCensus (i.e. first data export layer)* *AOI_County (i.e. after projection and datum set)* *AOI_County1k (e.g. 1 kilometer buffer)*	Input Layers: Output Layers: Other Comments:
4 Process streets (Targets)	2010 Census TIGER Lines - Features => All Lines (i.e. "edges") or… Features => Roads =>All	Data Download ▪ Census data or other UTRI Model ▪ Add UTRI_T (set to 0) ▪ Clip with AOI ▪ Project to project coordinates ▪ Classify ▪ Buffer to right-of-way (ROW) extent ArcToolbox ▪ Convert to raster at project resolution ***ATB=>Conversion Tools=>To Raster=>Feature to Raster***	03_UTRI-Street 03_UTRI-Blocks	AOI_Street vStreet rStreet	MTFCC	UTRI_S to raster cell	UTRI_S & Cell: S1100 = 4 S1200 = 3 S1300/S1400 = 2 Others important to your community = 1 All else = 0	Source: http://www.census.gov/cgi-bin/geo/shapefiles2010/main. UTRI_S is an integer value. (**Street**) Use 50' buffer from centerline or appropriate width based on street type for the segment or other local knowledge to create the polygon vector layer of street segments. Trees within the street buffer represent the area of concern for disaster planning if they can adversely affect people, facilities, or transportation.	Input Layers: Output Layers: Other Comments:
4a Process facilities (Targets)	Local or HSIP Gold	Data Download ▪ Data as available UTRI Model ▪ Add UTRI_F (set to zero) ▪ Clip with AOI ▪ Project to project coordinates ▪ Classify ▪ Buffer facility vicinity ArcToolbox ▪ Convert to raster at project resolution	04_UTRI-Facility	AOI_Facility vFacility rFacility	Name or description	UTRI_F to raster cell	UTRI_F & Cell: Hospitals=5 Fire, Police, Emergency Management Center = 4 Communication Towers, Water Treatment Plants, Water Towers, Waste Water Treatment Plants = 3 Schools, Parks, and	Source: Local or HSIP CD. UTRI_F is an integer value. (**Facility**) Buffer the facilities with a 100 meter or 200 meter radius. This represents the "immediate area" of risk for each critical facility.	Input Layers: Output Layers: Other Comments:

[3] ArcGIS is ArcCatalog, ArcMap, ArcToolbox, and ArcGIS Extensions; **TB** refers to ArcMap menu tools & toolbars; **ATB** refers to the ArcToolbox, **TOC** is the ArcMap table of contents, **RC** is 'right-mouse click'; **Dialog** is the input dialog window from a menu selection (e.g. ***New…***).
[4] "=>" Indicates ArcGIS menu selections.
[5] Suggested layer names; AOI is **area of interest** and used for clipping. Some steps will have multiple layers; use **v** prefix for vector and **r** prefix for raster in those cases (e.g. vStreet and rStreet represent the same data).

Objective: Users will step through the model, format input data layers from multiple sources, and create five raster layers that can be summed to create the UTRI. The final UTRI is then assigned back to the street segment layer for field verification, urban forest risk management, disaster planning, debris stratification, and/or response prioritization.

UTRI GIS Model Worksheet & Tool Description

Project Name: ___________________________________ Folder: ____ Geodatabase: ____________________________________ Coordinate System: ____ Resolution: _____ meters

Process Step	Data Source	GIS[3]/Model Processing[4]	Model Tools	Data Layer(s)[5]	Input Attribute	Output Attribute	Assignment or Reclass	Model Notes	GIS Processing Notes (As Built)
Process facilities (for Step **4b** that follows)		***ATB=>Conversion Tools=>To Raster=>Feature to Raster*** Data Download ▪ Data as available UTRI Model ▪ NA ArcToolbox ***ATB=>Analysis Tools=>Proximity=>Buffer***		vFacilityZone		UTRI_F	other locations where people congregate = 2 Others important to your community = 1 All else = 0	UTRI_F is an integer value as assigned in vFacility. Selected critical facilities (e.g. use two highest UTRI_F levels) should be buffered to a distance of 3000 meters to 5000 meters and used in the next step that identifies critical routes for these facilities in the AOI.	
4b Process streets (Access to Facilities)	2010 Census TIGER Lines - Features => Roads => Primary/Secondary vFacilityZone	Data Download ▪ Data as available UTRI Model ▪ Add UTRI_C (set to zero) ArcMap Tools ▪ Cumulative UTRI_F into UTRI_C ***RC=>[TOC Layer] Open Attribute Table*** ***TB=>Selection=>Select by attribute*** ***TB=>Selection=>Select by location*** ***RC=>[Attribute Name] Field Calculator*** ArcToolbox ▪ Convert to raster at project resolution ***ATB=>Conversion Tools=>To Raster=>Feature to Raster***	NA	vCFstreet rCFstreet	UTRI_F	UTRI_A to raster cell	Cumulative UTRI_A from the critical facility zones layer.	UTRI_A is an integer value. (ACCESS) This will be the GIS layer of primary roads in the AOI; assigned the risk ratings for all facilities that depend on that particular street or street segment; segment risk is cumulative for all critical facilities (CF) in vFacilityZone. When making calculations for street segment rating for facility access: *work alternatively in two layers: vFacilityZones, vCF_Streets* *set all UTRI_C to one (1) in v_CF_Streets* *use a "Select by Attributes…" for UTRI_F > x (rating desired)* *calculate UTRI_C = UTRI_C + x*	Input Layers: Output Layers: Other Comments:
5 Process population (Targets)	2010 Census or HSIP LANDSCAN	Data Download ▪ Census data or other UTRI Model ▪ Extract population in AOI ▪ Convert to vector (polygon) ▪ Project to project coordinates ▪ Calculate square miles (=acres/640; =square feet/27878400; =square meters/2589988) ▪ Calculate population/square mile ▪ Reclassify ArcToolbox ▪ Convert to raster at project resolution ***ATB=>Conversion Tools=>To Raster=>Feature to Raster***	05_UTRI-Census	vCensus rCensus		SqMiles Pop_SqMile UTRI_P to raster cell	Classification- Try Quantile, Natural Breaks (Jenks) or other symbol classification technique with four or five classes. UTRI_P & Cell: Class 5 = 4 Class 4 = 3 Class 3 = 2 Class 2 = 1 Class 1 = 0	Source: http://www.census.gov/cgi-bin/geo/shapefiles2010/main. Source: Local or HSIP CD. UTRI_P is an integer value. (POPULATION) When making calculations for population density: *set all Pop_SqMile to zero (0)* *use a "Select by Attributes…" for areas > 0 (square miles)* *calculate Pop_SqMile = Population/SqMiles* Areas with zero population / square mile should be set to UTRI_P = 0.	Input Layers: Output Layers: Other Comments:
6 Process tree canopy (Potential Tree Failure)	NLCD (USGS) NAIP (FSA)	Data Download ▪ Most current NLCD tree canopy ▪ Or, local tree canopy ▪ Or, classify most recent NAIP UTRI Model (NLCD) ▪ Clip to buffered AOI ▪ Reclassify (raster operation) ▪ Project to project coordinates ArcToolbox ***ATB=>Data Management Tools=>Raster=>Raster Processing=>Clip*** ***ATB=>Data Management Tools=>Projections and ATB=>Transformations=>Raster=>Project Raster*** ***ATB=>Spatial Analyst Tools=>Reclass=>Reclassify***	06_UTRI-Canopy	AOI_Canopy rCanopy	Cell Value	Cell value (UTRI_T)	Classification- Try Quantile, Natural Breaks (Jenks) or other symbol classification technique to create from five or eleven classes. Cell (UTRI_T): 91-100 = 10 81-90 = 9 71-80 = 8 61-70 = 7 51-60 = 6 41-50 = 5 31-40 = 4 21-30 = 3 11-20 = 2 1-10 = 1 0 = 0	Tree canopy is available from the MRLC: http://www.mrlc.gov/index.php The National Land Cover Database (NLCD 2001) tree canopy layer is downloaded as a raster and the cell value represents percent of tree canopy (from 0 to 100%) for the 30 meter pixel. This is a single file for the entire coterminous US and is in the Albers projection and in meters, WGS84. The MRLC Consortium Viewer at: http://gisdata.usgs.gov/website/mrlc/viewer.htm can be used to download an area that includes a single or multiple counties (not by county boundary but by rectangular selection area that you estimate will include your AOI). This raster file can then be clipped with the AOI. When downloading from the viewerthe default is to get the landcover dataset. To specify tree canopy, click on the download tab (in the right panel), and uncheck landcover and select tree (forest) canopy). Then make your download area with the selection box tool (in the left panel near the bottom). ArcGIS Spatial Analyst Extension is required for most of the operations in this and the following steps.	Input Layers: Output Layers: Other Comments:
6a Area of Interest Mask	vStreet	Data Download ▪ Streets from Step ❸		vAOImask rAOImask	Select any integer attribute with a value of 1	Cell	Assign value of 1 to the areas within the AOI that should have a risk index	Use approximately 3x the distance used in Step 3; 150' buffer from centerline or appropriate width based on street type for the segment or other local knowledge to create the polygon	Input Layers:

Objective: Users will step through the model, format input data layers from multiple sources, and create five raster layers that can be summed to create the UTRI. The final UTRI is then assigned back to the street segment layer for field verification, urban forest risk management, disaster planning, debris stratification, and/or response prioritization.

UTRI GIS Model Worksheet & Tool Description

Folder: ____

Project Name: ___________________________________ Geodatabase: ___________________________________ Coordinate System: ____ Resolution: _____ meters

Process Step	Data Source	GIS[3]/Model Processing[4]	Model Tools	Data Layer(s)[5]	Input Attribute	Output Attribute	Assignment or Reclass	Model Notes	GIS Processing Notes (As Built)
		UTRI Model ▪ Buffer to a distance that exceeds right-of-way (ROW) extent ArcToolbox ▪ Convert to raster at project resolution ***ATB=>Conversion Tools=>To Raster=>Feature to Raster***			(or due field calculator to set it)		calculated; otherwise **NODATA**.	vector layer of street segments. When buffering, select "merge polygons". This raster layer will be used to mask OUT all areas that are beyond the buffer.	Output Layers: Other Comments:
7 Create UTRI (Raster)	rStreet rFacility rCFstreet rCensus rCanopy rAOImask	Data Download ▪ NA UTRI Model ▪ Run model to sum individual layer cell values ArcToolbox ***ATB=>Spatial Analyst Tools=>Map Algebra=>Raster Calculator*** ***ATB=>Spatial Analyst Tools=>Reclass=>Reclassify***	07_UTRI-Index	rUTRIsum rUTRI	UTRI_S (cell) UTRI_F (cell) UTRI_A (cell) UTRI_P (cell) UTRI_T (cell)	Cell Value	Classification- Try Quantile, Natural Breaks (Jenks) or other symbol classification technique to create four or five classes. Once break points are determined use the raster reclassify tool to create a final reclassified raster layer.	Reclassification of input layers may be performed to create more suitable risk index upon summation. Use ArcMap ***RC=>Properties->Symbology*** dialog to view the Jenks Natural Breaks to set and test breaks in the data prior to reclassification. The final rUTRI layer is created from the reclassification of this rUTRIsum into four classes: 1:Low, 2:Moderate, 3:High, and 4:Very High. See Appendix D for ***Raster Calculator*** details for syntax and weighting of layers.	Input Layers: Output Layers: Other Comments:
8 Create UTRI (Vector)	rUTRI	Data Download ▪ NA UTRI Model ▪ NA ArcToolbox ▪ Convert UTRI raster to vector and assign UTRI risk rating to street segments for field verification and stratification components. ***ATB=>Conversion Tools=>From Raster=>Raster to Polygon*** and… ***ATB=>Analysis Tools=>Overlay=>Spatial Join*** or possibly… ***ATB=>Analysis Tools=>Overlay=>Identify*** or possibly… ***ATB=>Analysis Tools=>Overlay=>Union***	08_UTRI-R2V	vUTRI	NA	Cell values summed to UTRI (grid_code)	NA	After conversion to a polygon layer, the original street layer (AOI_Street) is assigned the corresponding UTRI value (obtained in the conversion from raster). A street segment may intersect from 1 to n raster cells that are summed into the final UTRI and assigned to the street layer. Note: Only integer raster layers can be converted to polygon features. If you create a floating point rater in step **7** you will need to convert it to integer for this step (see Appendix D).	Input Layers: Output Layers: Other Comments:
9 Create field verification report	NA	UTRI Model ▪ NA ArcToolbox ▪ Can use Crystal Reports, or read DBF in Excel or other spreadsheet to generate report	NA		NA	NA	NA	Generates street segment field verification form from street layer for urban forester. Includes a color coded map(s) and corresponding list(s) of street segments keyed to map. Generates standard UTRI map from an ArcMap template. Updated street segment map (and list) after verification is used for: 1. Comprehensive risk management (risk zones) 2. Tree risk assessment and rating 3. Pre-disaster mitigation 4. Urban forest management (planting)	Input Layers: Output Layers: Other Comments:
10 Produce a stratified random sample (street segments) for debris estimation in i-Tree Eco or i-Tree Streets. Produce UTRI street segment map.	NA	UTRI Model ▪ NA ArcToolbox ▪ NA Other Tools ▪ Stratified Sampling Tools	NA		NA	NA	NA	Biogeography Branch's Sampling Design Tool for ArcGIS http://ccma.nos.noaa.gov/products/biogeography/sampling/ or Hawth's Analysis Tools for ArcGIS v9.3 http://www.spatialecology.com/htools/overview.php or the Geospatial Modeling Environment http://www.spatialecology.com/gme/ or Iowa State PM2082-09n ***Using Field Calculator: Create Random Values***. www.extension.iastate.edu/Publications/PM2082-09N.pdf	Input Layers: Output Layers: Other Comments:

<u>Additional UTRI Model Processing Notes:</u>

GIS data source (and quality) will control the amount of editing needed prior to using the model and the quality and functionality of the model output (i.e. the risk index calculated, field forms, reports, and maps). The notes below will provide some indication of the most important considerations when using the data and model. Editing may also be influenced by data processing and reporting standards within your agency.

Step 1: **Assemble Data Layers Needed**

Obtain necessary layers (often as ERIS ArcGIS shapefiles) that will be needed in Steps 1-10 (AOI, streets, facilities, population, canopy). Layers not required by the model may also be obtained and used to develop more familiar map products for reports and field use (e.g. adding a stream network gives field crews additional landscape reference points).

The project resolution (size of the raster cells) will probably be controlled by the tree canopy layer which will be the only source data acquired that is a raster layer.

Step 2: **Create a Personal/File Geodatabase for the Project**

A well defined folder structure and geodatabase, while not required, will help organize your original data layers needed for the model and the intermediate and final layers needed to complete UTRI modeling.

If a geodatabase is not used then you may also want to create a folder for “FinalModelLayers”.

The “SourceData” folder may also have subfolders for the major modeling components: Boundaries, Transportation, Facilities, Canopy, and Others. This is particularly helpful if significant editing and data manipulation is required prior to importing the data layer into the project geodatabase.

Step 3: **Create Project Boundary**

Input: Vector features needed to create the combined area of interest for the urban tree risk assessment.

Output: A vector feature (polygon) that represents the AOI; it may or may not have an edge buffer.

The UTRI Model, while originally intended for a county focus, may be used for any smaller or larger area of interest (AOI) desired. Regardless of the spatial extent of your AOI the type of reporting should be determined at the beginning of the process (e.g. at the AOI or sub-AOI levels). For example, if the AOI is a county but you also intend on reporting at the municipal level within the county then municipal boundaries will be needed at the reporting and map generation stages. In addition, if those municipal boundaries cross county lines then adjacent county data (e.g. tree canopy, population, streets, facilities) will be need for the analysis.

Once the final AOI boundary is determined a buffer may be desirable/useful particularly when modeling an area that is not based on political boundaries.

Step 4: **Process Streets (Targets)**

Input: Vector features (lines) representing public streets and roads.

Output: A raster feature that represents the street right-of-way (ROW) with the cell values rated for risk (e.g. from 0-4) based on street type (MTFCC); UTRI_T is the vector layer attribute to use when creating the raster.

Three types of Census TIGER/Line files are available for streets in shapefile format.

At the Census TIGER/Line website: use **Features=>Roads**.

These include: “primary and secondary roads” and “all roads”. Downloaded files have the file name structure like:

- tl_2010_01_prisecroads.zip
- tl_2010_01051_roads.zip

These are typically 1:100000 scale derived centerlines (check the metadata).

At the Census TIGER/Line website: use **Features=>All**.

This will be the “edges” file that includes all lines for the county; streets can be created as a subset using the ROADFLG attribute (***Menu=>Selection=>Select by attributes***).

Downloaded files have the file name structure like:

- tl_2010_01051_edges.zip

These are at a 1:24000 scale (check metadata) that have streets broken into smaller segments. For example, in Elmore County (AL) the 1:24000 scale street file contains 12,000+ segments while the 1:100000 street file contains only about 5,000 segments. Either may be used for the UTRI modeling.

The data structure of TIGER files may contain many attributes not needed for this model: Recommended minimum requirements are unique street ID (not FID or OBJECTID), street name, road classification, and length. Ideally the street name should be the base name of the street including the type modifier as suffix (i.e. Street, Highway, Road, Boulevard, Circle, Court, etc. or their abbreviations); any direction prefix should be at the end of the name or in a unique attribute (e.g. “High St N” not “N. High St”). The street name attributes may have to be manipulated into this format if desired.

The “edges” file also contains the address range of the street segment. The address ranges in these files (LFROMADD, LTOADD, RFROMADD, RTOADD) do not consistently have the lowest number (or highest) in the “from” component. A more readable field report form can be created if a new attribute is created (a text field) that assembles the block address range that consistently runs from smallest address to largest and that always looks at the right addresses (or left if there are no rights).

This is the first of two GIS street layers needed for the UTRI model.

1. **all roads are needed to develop a risk prioritized street layer based on the type of road (using the attribute MTFCC or similar)**
2. primary and secondary street GIS layer that includes federal and state highways is used in the critical facility layer processing step

For “all roads” (or “edges”) processing the street centerlines are buffered to a distance that will encompass any street-side trees that could affect the public ROW (right-of-way). We currently use 50’ from the centerline for a combined buffered street width of 100’. Other widths may be appropriate for your analysis and should be used as desired.

Step 4a: **Process Facilities (Targets)**

Input: Vector features (points) representing critical facilities in the AOI.

Output: A raster feature that represents the area of concern near the facility with the cell values rated for risk (e.g. from 0-4) based on facility type; UTRI_F is the vector layer attribute to use when creating the raster.

The facilities will be represented in the UTRI model by two components:

1. a simple circular zone (e.g. 100 meter or 200 meter radius) that accounts for the “immediate area” near the facility, and
2. streets or street segments that support the facility (i.e. access to/from the facility)

The first facility layer is a simple point buffer (e.g. 100 or 200 meters) with the type of facility rating reclassified and assigned to UTRI_F and converted to a raster layer.

> Note: If file errors occur for “Input Features” in the Feature to Raster (or Polygon to Feature) dialog try using the folder selection icon and select the vector (polygon) file from the geodatabase (or list of shapefiles).

Input: Vector features (points) representing critical facilities in the AOI.

Output: A vector feature (polygons) that will encompass primary and secondary roads of importance for this facility; carries the UTRI_F from the facility.

The second facility layer (used in step 4b that follows) is a larger buffer on the highest ranked facilities (e.g. the top two facility rating classes) that will be used to select access routes to and from these facilities. For this buffer use 3000 meters to 5000 meters. Use the same UTRI_F value assigned in the “immediate area” buffer. This is the **Facility Zone** layer (e.g. vFacilityZone) and does not have to be converted to a raster.

Step 4b: **Process Streets (Access to Facilities)**

Input: A vector feature (polygons) that will encompass primary and secondary roads of importance for this facility; carries the UTRI_F from the facility; from 4a.

Output: A raster feature that represents the street right-of-way (ROW) with the cell values rated for risk (e.g. from 1-n) based on cumulative UTRI_F of all facilities that depend on the particular street or street segment; UTRI_C is the vector layer attribute to use when creating the raster.

This is the second of two GIS street layers needed for the UTRI model.

1. all roads are needed to develop a risk prioritized street layer based on the type of road (using the attribute MTFCC or similar)
2. **primary and secondary street GIS layer that includes federal and state highways is used in the critical facility layer processing step**

For “primary and secondary” processing the street segments are spatially selected using the facility zones and the facility risk ratings (UTRI_F) are cumulatively assigned to UTRI_C. This creates a second street layer that represents the overall importance (or risk) that specific streets have for access to and from facilities. This layer is converted to a raster.

Step 5: **Process Population (Targets)**

Input: A population layer (feature); may be either vector (e.g. Census blocks) or raster (e.g. LandScan).

Output: A population raster layer with the cell values rated for risk (e.g. from 0-4) based on population density (e.g. population/square mile; UTRI_P is the vector layer attribute to use when creating the raster.

This step begins with either a Census polygon or LandScan raster. Data manipulation is done in a vector layer (polygon) so raster to vector conversion may be necessary to being (projection and datum may be set at that time).

> Note: If converting an input population raster to a polygon feature do NOT "simplify polygons" (i.e. leave that optional box in the conversion dialog unchecked).

Other ArcGIS extensions (like XTools) can be used to calculate area in square miles.

> Note: If using the attribute table's "Field Calculator" to calculate population/square mile, a "Select by Attribute…" should be made for areas > 0 square miles to avoid a "divide by zero" error.

The natural breaks facility in ***RC: Properties=>Symbology*** can be used to help visually set the classification breaks for the reclassification.

Step 6: **Process tree canopy (Potential Tree Failure)**

Input: A raster layer that has cell values for percent tree canopy or (on higher resolution urban tree canopy (UTC) layers the landcover (e.g. water, canopy, impervious, bare soil, and grass).

Output: A tree canopy raster layer with the cell values rated for risk (e.g. from 0-4) based on canopy density.

If using NAIP or other imagery use or convert to project resolution during classification.

When clipping raster layers from within ArcMap and using ***Data Management Tools=>Raster=>Raster Processing=>Clip*** check (✔) the "Use input features" to clip with AOI boundary.

Step 6a: **Create AOI Mask**

Input: Vector features (lines) representing public streets and roads in Step 3.

Output: A raster layer that will be used to "mask out" areas of the AOI of no interest (e.g. areas that are not near streets or public facilities. The cell values are set to 1 and areas of no interest are set to **NoData**.

Create a vector (polygon) layer by buffering the street centerline from Step 3. The buffer should exceed the buffer used to create vStreet and rStreet and is approximately 3x the distance (e.g. 150') from the centerline.

[combine polys; then set 1 attrib to value of 1]

This raster layer will be used to mask OUT all areas that are beyond this buffer.

Step 7: **Create UTRI Layer (Raster)**

Input: Raster layers: rStreet, rFacility, rCFstreet, rPopulation, rCanopy, rAOImask

Output: An intermediate raster layer (rUTRIsum) that sums the input layers and a final raster layer (rUTRI) that is reclassified into four classes that correspond to risk zones in **Urban Tree Risk Management: A Community Guide to Program Design**.

Step 8: **Create UTRI Layer (Vector)**

Input: rUTRI

Output: A vector (polygon) layer (e.g. vUTRI) that can be used to update the street layer with the UTRI for the segment. Or combine the segment UTRI value with the street segment in some fashion.

The conversion to a polygon is simply ***TB=>Conversion Tools=>From Raster=>Raster to Polygon***. Various GIS methods may be used to accomplish this final task that produces the layer used for the map and field report that includes both UTRI and the unique segment identification.

Step 9: **Create Field Verification Report**

Input: vUTRI or vStreet (updated with UTRI)

Output: A listing of the street segments sorted alphabetically by street and in descending order of UTRI. Unique segment indices are used on corresponding map for field checks.

This can be accomplished through the attribute table for the layer and ***Reports=>Create report***.

Step 10: **Produce a Stratified Random Sample for Debris Estimation**

Input: vUTRI or vStreet (updated with UTRI)

Output: A list of the street segments (plots) randomly selected by strata.

Various GIS methods may be used to accomplish this task that randomly selects street segments (as plots) for debris estimation samples. Each UTRI value (1 through 4) is treated as strata. Plots selected should be approximately:

- UTRI 4: 40%
- UTRI 3: 30%
- UTRI 2: 20%
- UTRI 1: 10%

The final street segment layer (e.g vUTRI or vStreet) that contain the UTRI can be modified to add an attribute **RANDSEL** and in the field calculator fill each record using the function: ***Rnd***. Generate randm numbers for each strata between 0 and 1. Then, for example, if you are interested in 20% of the segments in that stratum, merely take all segments with a random number ≤ 0.2.

<u>ArcGIS Raster Calculator & **NoData** Values:</u>

Raster layers (i.e. ESRI Grids) may be created for streets, facilities, facility access, population, and canopy with **NoData** cell values (i.e. null values NOT zeroes). In the final step of the UTRI model, where the raster layers are summed, the following or similar syntax[6] should be used[7]:

with a layer weighting factor…

```
(Con(IsNull("Layer1"),0,"Layer1") * 1.0)+\
(Con(IsNull("Layer2"),0,"Layer2") * 1.0)+\
(Con(IsNull("Layer3"),0,"Layer3") * 1.0)+\
(Con(IsNull("Layer4"),0,"Layer4") * 1.0)+\
(Con(IsNull("Layer5"),0,"Layer5") * 1.0)+\
(Con(IsNull("AOIMask"),"AOIMask",0))
```

without a layer weighting factor…

```
Con(IsNull("Layer1"),0,"Layer1") +\`
Con(IsNull("Layer2"),0,"Layer2") +\
Con(IsNull("Layer3"),0,"Layer3") +\
Con(IsNull("Layer4"),0,"Layer4") +\
Con(IsNull("Layer5"),0,"Layer5") +\
Con(IsNull("AOIMask"),"AOIMask",0)
```

The "IsNull" function evaluates each raster cell and returns a "true" (i.e. value of 1) if the cell is **NoData**.

The "Con" function is a conditional statement that substitutes a zero (0) if the cell is currently **NoData,** otherwise it uses the value found.

AOIMask is a raster layer that has a cell value of one (1) only in the area that you would like to evaluate for the final risk layer (e.g. rUTRI). The conditional statement with this layer is reversed so that **NoData** values remain and other values are replaced with zero (0) so that the mask does not affect the cumulative result (i.e. only the layers for: streets, facilities, access to facilities, population, and canopy contribute values for summation).

The desired code above may be copied and pasted into the raster calculator; then change the "Layer*n*" names appropriately for your project.

---

[6] Function names **ARE** case sensitive.
[7] The back slash character "\" is the line continuation indicator.

During the summation into the final combined layer (i.e. rUTRI) the layers may optionally be weighted by modifying the component "*** 1.0**". For example, use "*** 2.0**" to make a layer 2x its calculated weight, or "*** 0.5**" to make it ½ the calculated weight.

Actual example with layer names substituted and no weighting:

```
Int( \
  (Con(IsNull("rElmoreTallassee_Streets_2"),0,"rElmoreTallassee_Streets_2") * 1.0) + \
  (Con(IsNull("rElmoreFacilities200m_2"),0,"rElmoreFacilities200m_2") * 1.0) + \
  (Con(IsNull("rElmoreTallassee_CFS_ZoneArea_2"),0,"rElmoreTallassee_CFS_ZoneArea_2") * 1.0) + \
  (Con(IsNull("rLandScan2009UTM16N"),0,"rLandScan2009UTM16N") * 1.0) + \
  (Con(IsNull("rCanopyRC2"),0,"rCanopyRC2") * 1.0) + \
  (Con(IsNull("rAOImask50m"), "rAOImask50m",0)) \
+ 0.5)
```

<u>Integer and Floating Point (i.e. Real) Raster layers:</u>

The raster layer resulting from a calculation using real number weighting factors will be a floating point raster. Floating point raster layers cannot be converted to polygon features. If a final polygon feature (e.g. vUTRI) is needed (e.g. for reporting) then it must first be converted to an integer raster layer.

The example above uses the Int() function to convert the final summation to an integer raster during the one pass through the raster calculator. The constant 0.5 is added to each floating point raster cell value from the main calculation to force rounding (as opposed to truncation).

Alternatively, if weighting factors are only required to be whole numbers (e.g. 1, 2,3) then using them without a decimal (e.g. 1.0) will create an integer raster as needed.

And finally, if the floating point raster is to be reclassified, the conversion to integer can occur at that time.