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TRANSIMS Training Course at TRACC

Transportation Research and Analysis Computing Center

Part 11

GIS Concepts and GIS Tools in TRANSIMS

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Contents

Part 1

Introduction to GIS Concepts and Tools

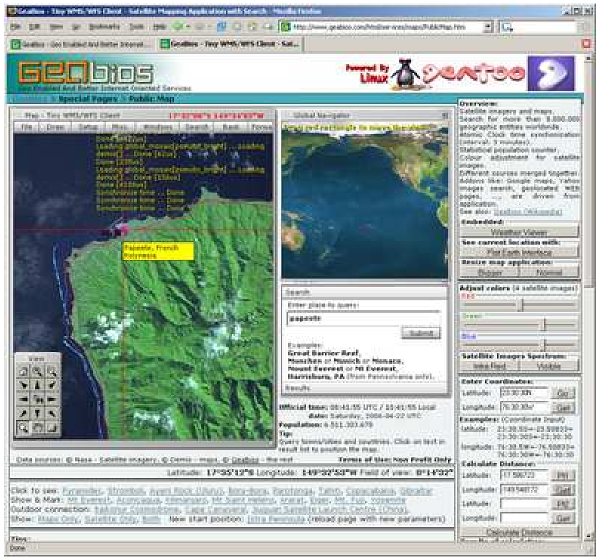
GIS Introduction

- GIS stands for Geographical Information System
- GIS has become an industry standard for the exchange of geographical information such as cartography and satellite imagery
- GIS links visual objects to database fields for advanced data processing
- GIS simplifies complicated tasks such as reprojection between incompatible coordinate systems
- GIS is an essential tool as a graphical user interface for data analysis and data entry

- ***Wikipedia:*** *A geographic information system (GIS) is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. In the strictest sense, it is a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, maps, and present the results of all these operations. Geographic information science is the science underlying the geographic concepts, applications and systems, taught in degree and GIS Certificate programs at many universities.*

Use of GIS in TRANSIMS

- TRANSIMS makes use of GIS mostly for the presentation of results
  - Road and transit networks in form different formats
  - Visualization of individual or groups of travel plans
  - Combination of TRANSIMS data with other data sources
    - *Satellite imagery*
    - *Zoning information*
    - *Other road networks for comparison*
- GIS is also used for data entry and editing
  - Creation of points, lines, and polygons
  - Definition of polygons for subarea microsimulation
  - Network refinement and network data editing
- Typically, the ESRI ArcGIS software is being used
- Alternatives are available, such as uDig



Projections

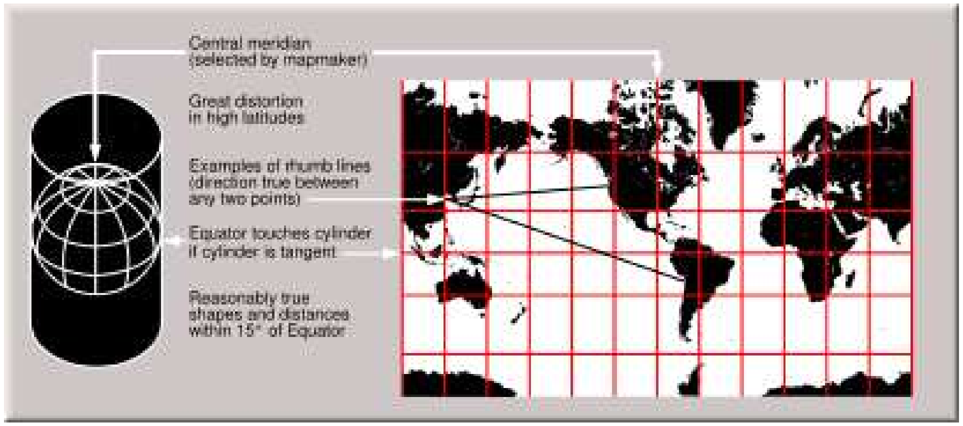
- A map projection is any method used in cartography (mapmaking) to represent the two-dimensional curved surface of the earth or other body on a plane. The term "projection" here refers to any function defined on the earth's surface and with values on the plane, and not necessarily a geometric projection.

- Flat maps could not exist without map projections, because a sphere cannot be laid flat over a plane without distortions. Flat maps can be more useful than globes in many situations: they are more compact and easier to store; they readily accommodate an enormous range of scales; they are viewed easily on computer displays; they can facilitate measuring properties of the terrain being mapped; they can show larger portions of the earth's surface at once; and they are cheaper to produce and transport. These useful traits of flat maps motivate the development of map projections.

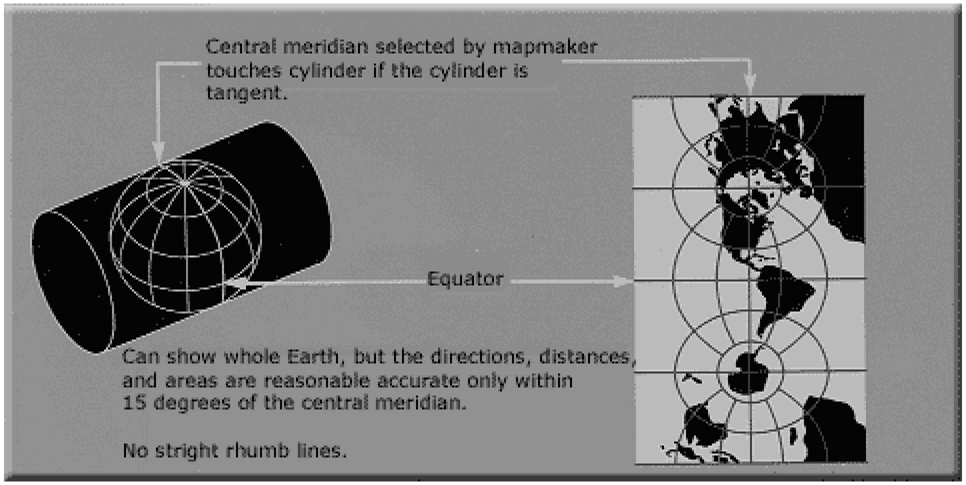
Source: Wikipedia

Projection Systems

- The Mercator projection shows courses of constant bearing as straight lines. While common, scholars advise against using it for reference maps of the world because it drastically inflates the high latitudes.



- This Transverse Mercator projection is mathematically the same as a standard Mercator, but oriented around a different axis.



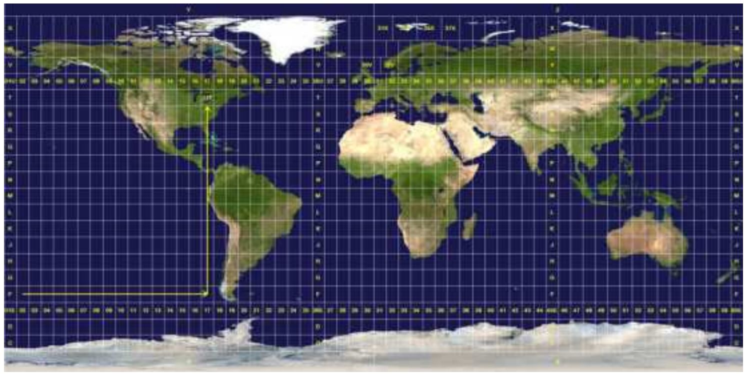
Source: Wikipedia

Universal Transverse Mercator (UTM)

- UTM is the basis for all TRANSIMS coordinates

- The UTM system divides the surface of the Earth between 80°S latitude and 84°N latitude into 60 zones, each 6°of longitud e in width and centered over a meridian of longitude. Zones are numbered from 1 to 60. Zone 1 is bounded by longitude 180°to 174°W and is centered on the 177th West meridian. Zone numbering increases in an easterly direction.

- Each of the 60 longitude zones in the UTM system is based on a Transverse Mercator projection, which is capable of mapping a region of large north-south extent with a low amount of distortion. By using narrow zones of 6°in width, and reducing the scale factor along the central meridian by only 0.0004 (to 0.9996, a reduction of 1:2500) the amount of distortion is held below 1 part in 1,000 inside each zone.



Source: Wikipedia

UTM Zones for the Continental United States

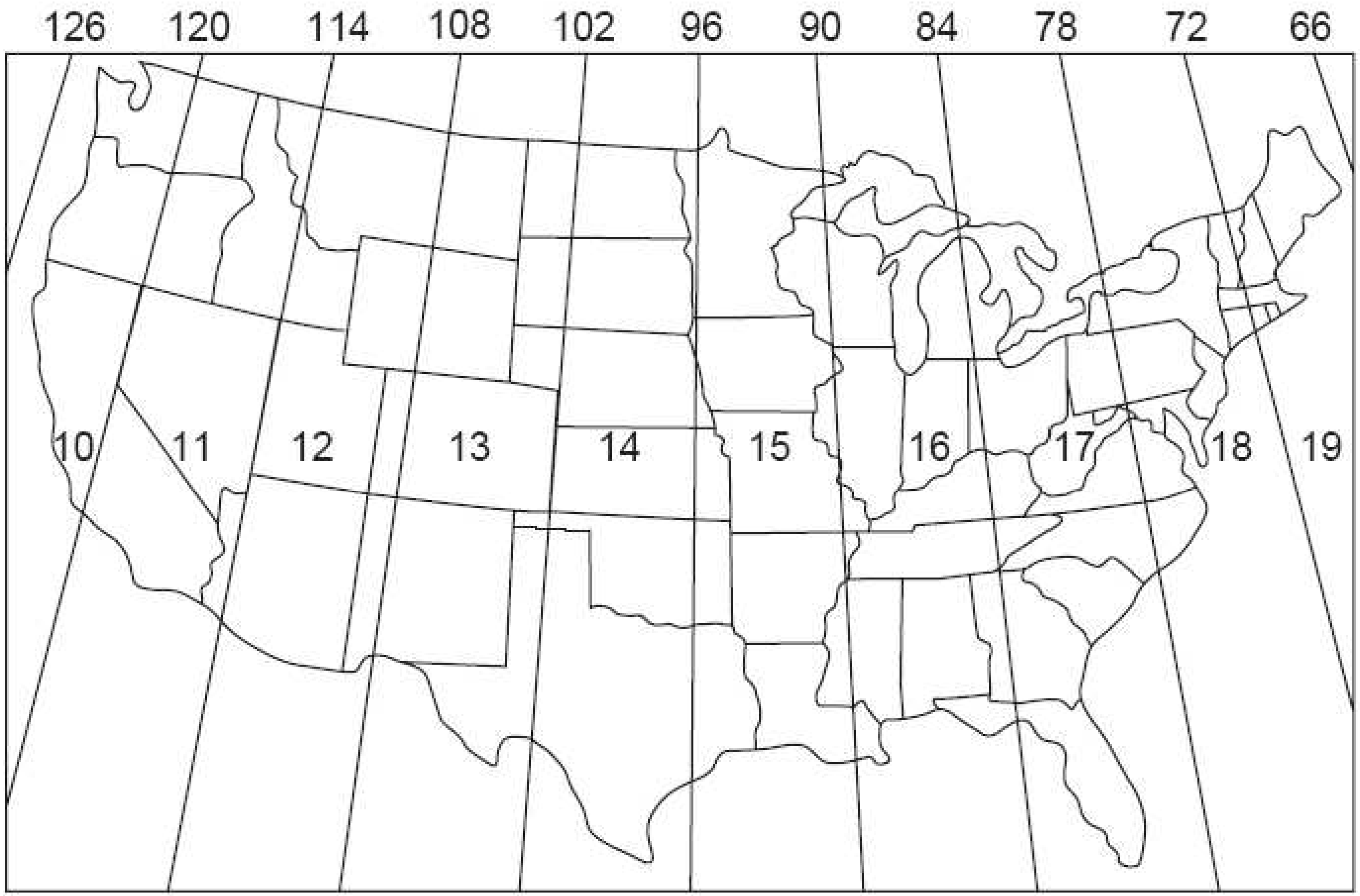


Figure 1. The Universal Transverse Mercator grid that covers the conterminous 48 United States comprises 10 zones—from Zone 10 on the west coast through Zone 19 in New England.

Source: Wikipedia

Northing, Easting, False Northing, and False Easting

- A position on the Earth is referenced in the UTM system by the UTM longitude zone, and the easting and northing coordinate pair. The easting is the projected distance of the position from the central meridian, while the northing is the projected distance of the point from the equator. The point of origin of each UTM zone is the intersection of the equator and the zone's central meridian.
- In order to avoid dealing with negative numbers, the central meridian of each zone is given a "false easting" value of 500,000 meters. Thus, anything west of the central meridian will have an easting less than 500,000 meters. For example, UTM eastings range from 167,000 meters to 833,000 meters at the equator (these ranges narrow towards the poles). In the northern hemisphere, positions are measured northward from the equator, which has an initial "northing" value of 0 meters and a maximum "northing" value of approximately 9,328,000 meters at the 84th parallel -- the maximum northern extent of the UTM zones.
- In the southern hemisphere, northings decrease as you go southward from the equator, which is given a "false northing" of 10,000,000 meters so that no point within the zone has a negative northing value.

Source: Wikipedia

State Plane Coordinate Systems

- The State Plane Coordinate System (SPS or SPCS) is a set of more than 100 geographic coordinate systems designed for specific regions of the United States. Each state contains one or more state plane zones, the boundaries of which usually follow county lines. The system is widely used for geographic data by state and local governments.
- The system is highly accurate within each zone. Outside a specific state plane zone accuracy rapidly declines, thus the system is not useful for regional or national mapping.
- Each state plane zone is based on either a Transverse Mercator projection or a Lambert conformal conic projection. The choice between the two map projections is based on the shape of the state and its zones. States that are long in the east-west direction are typically divided into zones that are also long east-west. These zones use the Lambert conformal conic projection, because it is good at maintaining accuracy along an east-west axis. Zones that are long in the north-south direction use the Transverse Mercator projection because it is better at maintaining accuracy along a north-south axis. One part of one state, the panhandle of Alaska, uses the Oblique Mercator projection, since that region lies on a diagonal.

Source: Wikipedia

Projection Summary

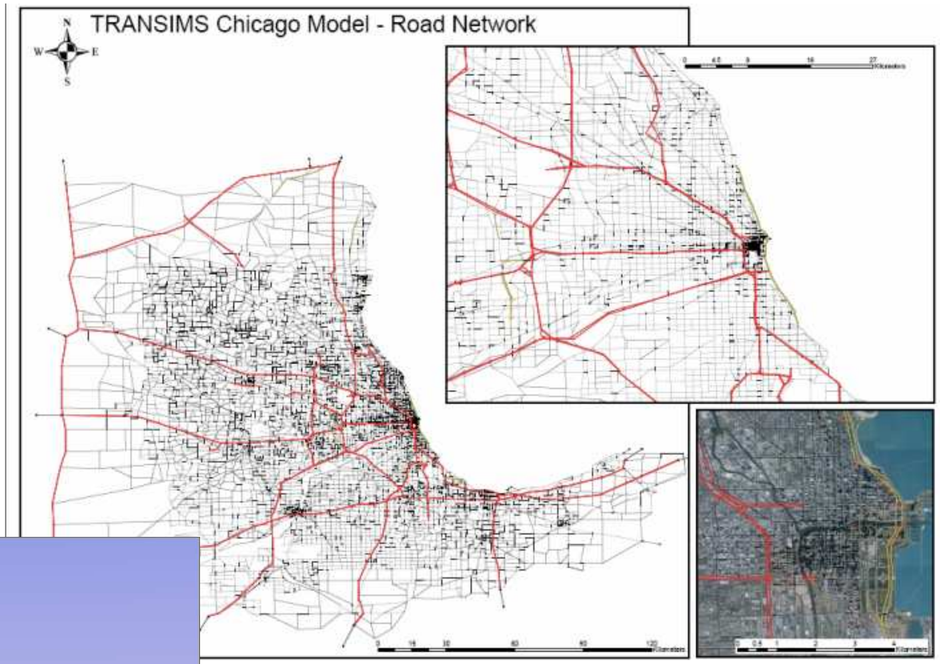
- Thousands of well-defined and commonly used coordinate systems are being used for existing geospatial data
- Metropolitan planning organizations are typically using maps and data based on the state plane coordinate system, which has roughly the same advantages as the UTM system, but provides less distortion
- To create maps, great care must be taken to identify all used coordinate systems and to avoid unnecessary conversions due to loss of quality
- If GIS data sources don't seem to overlap in your software, it's most likely that there is a reprojection mismatch
  - Identify the projection systems for each layer of source data
  - Identify the projection system for your current map
  - Determine whether the data can be meaningfully displayed in your chosen common projection system
- It is essential to understand the fundamental projection logic to work effectively with geospatial information

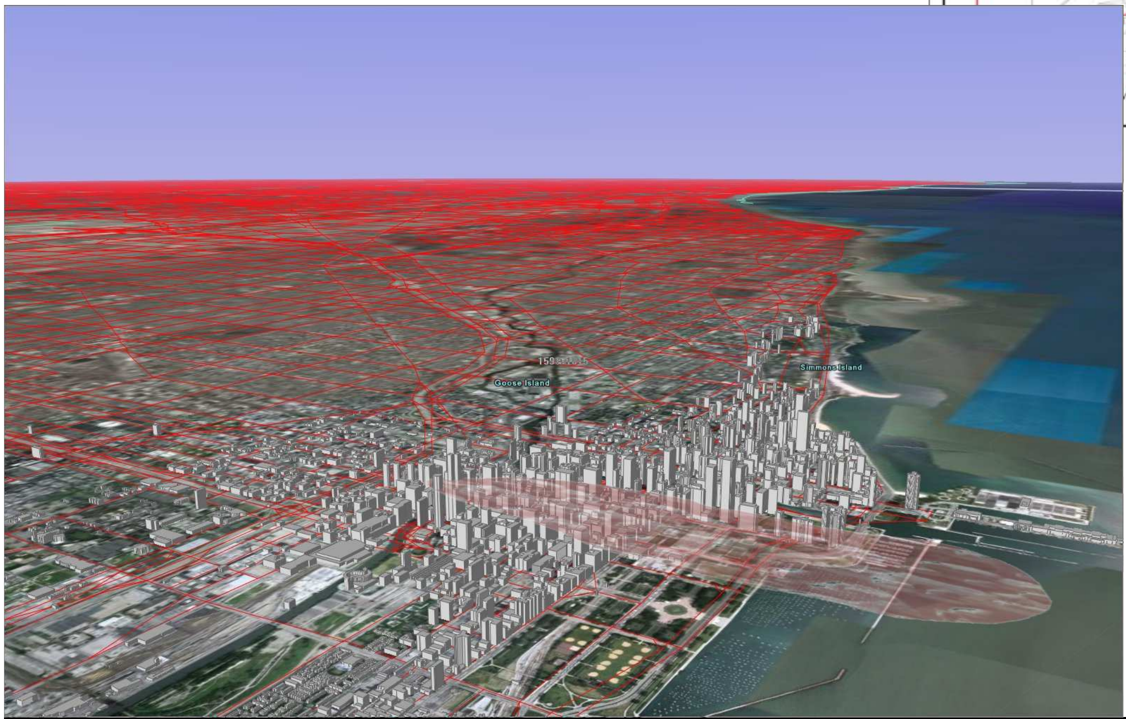
GIS Data Formats

- GIS data is typically split into two categories
  - Vector data
  - Raster data
- Vector data
  - Typical examples are points, lines, polygons
  - Used in TRANSIMS for roads, rail lines, parking and activity locations, routes, zoning information, and many more
  - Can be easily layered in a typical GIS application
- Raster data
  - Typical examples are satellite images, but also any other form of geo-coded imagery
  - Very useful for "field" data that is continuous across an area
  - Currently used in TRANSIMS for satellite imagery

GIS Examples

- Showing mixed data sources at varying resolutions
- Showing the same data sources in different applications
- Mix raster and vector information





- Optimizing GIS representation for paper-based or interactive applications
- Distribute geospatial information on-line through the Internet

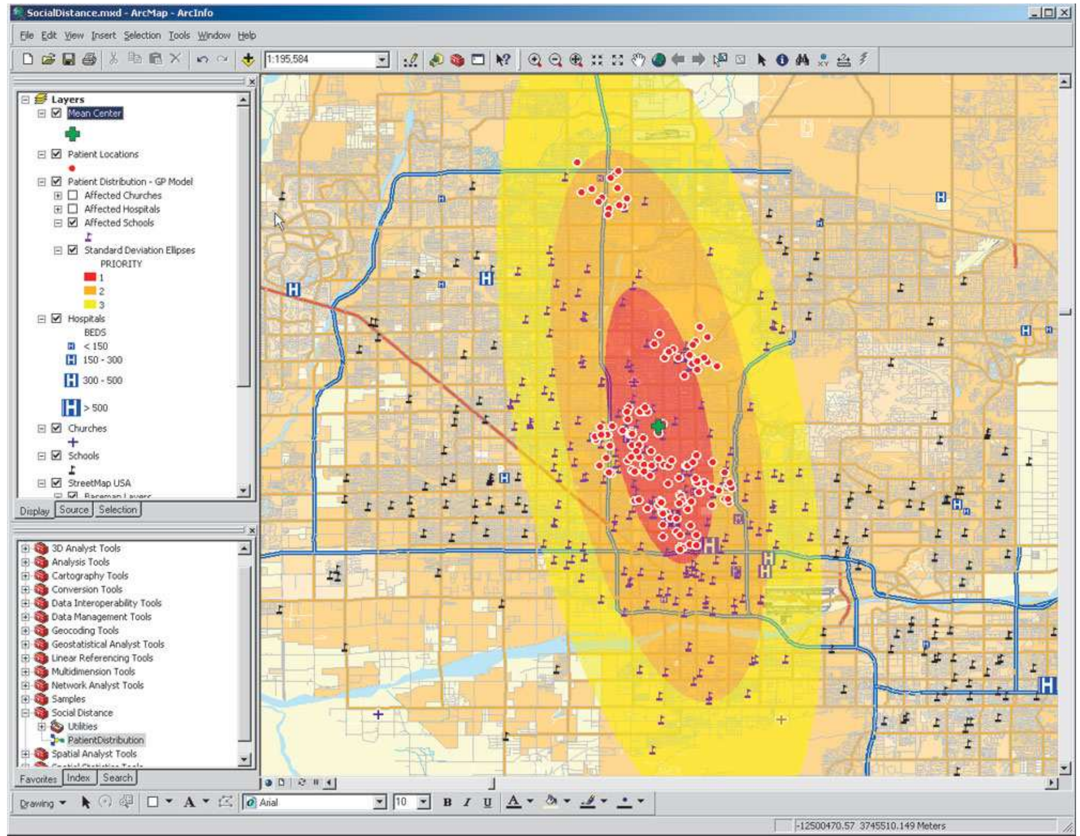
GIS Capabilities and Advantages

- Creating a representation from many different data sources in many different formats
- Automating many otherwise complex procedures
- Most important:
  - GIS data is not purely visual, but associates tabular data with visual objects
  - This is essential for applications such as TRANSIMS, because the visual line representing a link is associate with many different attributes, such as
    - *Lines: Speed limits, free speed, effective link length, number of lanes, directional information, toll amounts, and much more*
    - *Points: Activity and parking locations, traffic signals, signs, etc.*
    - *Areas: Population density, zoning restrictions, population, etc.*
  - Lines don't need to be straight, and can be bent using shape points
  - Areas are enclosed by polygons, but may have holes

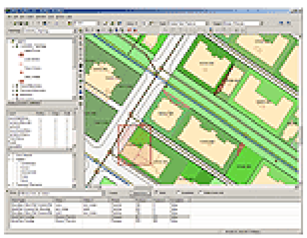
GIS Object Attributes

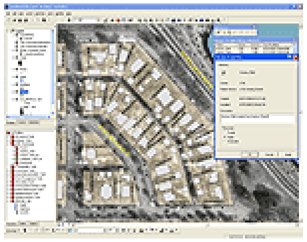
- GIS object attributes can be used to improve visualization
  - Database fields can be used to set the line or area colors
  - Database fields may indicate what symbol to draw in a specific location (stop sign, yield sign, and so on)
- In some powerful GIS operations, fields can be linked to related fields in other databases to create complex queries
  - GIS is typically used for post-processing of geospatial information, but may actually implement some analytical functions
- GIS allows to edit both the visual as well as the tabular information in a convenient and consistent way
  - Accessing database fields based on interactive map locations rather then a numerical search by index number in a database table

GIS Applications: ArcGIS



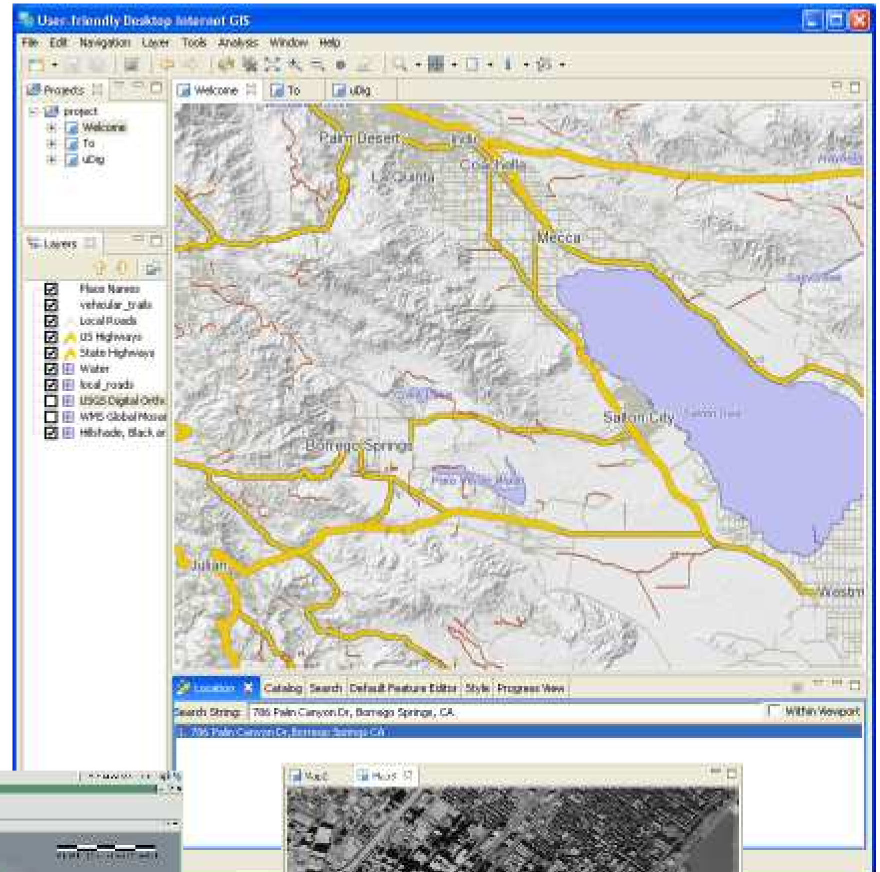
- ESRI is the best known GIS application vendor, providing ArcGIS
  - Very powerful application
  - Expensive licensing terms
  - Essential when creating paper-based maps
  - Has complex database capabilities
  - Has powerful editing capabilities
  - Provides many data analysis tools
  - Is typically available to GIS professionals

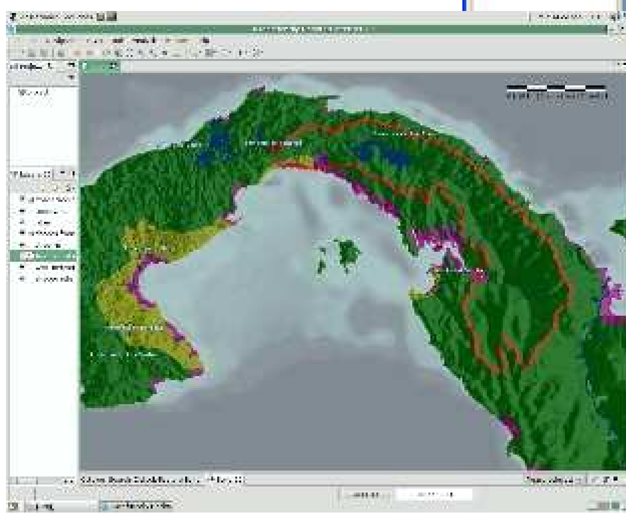


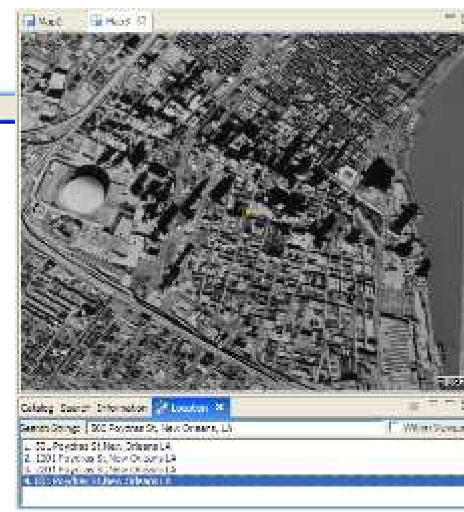


GIS Applications: uDig

- Available from Refractions Inc for free
- Is based on the same concepts as ArcGIS with emphasis on easy operation
- Printing capabilities are currently very limited
- Allows important feature such as data editing
- Is very useful for basic TRANSIMS needs
- Compatible with Windows and Linux







Typical functionality of GIS applications

- Data is provided to GIS applications in form of layers
- A layer is a collection of visual elements such as points, lines, polygons, that are associated with records in a database table
  - Example: Streets in DuPage county
  - Example: Traffic signals in Chicago
  - A layer is therefore a collection of similar items in a specific geographic area
- Several layers are combined to create a map
  - The user may combine several different types of objects and data in a single map
  - The user may also combine the same type of data from several different regions into the same map
- A layer may also be geo-coded graphical data such as satellite imagery
  - Typically provided as web services for on-demand download of re-projected data for the chosen viewport (area and projection)

GIS Data Sources and Formats

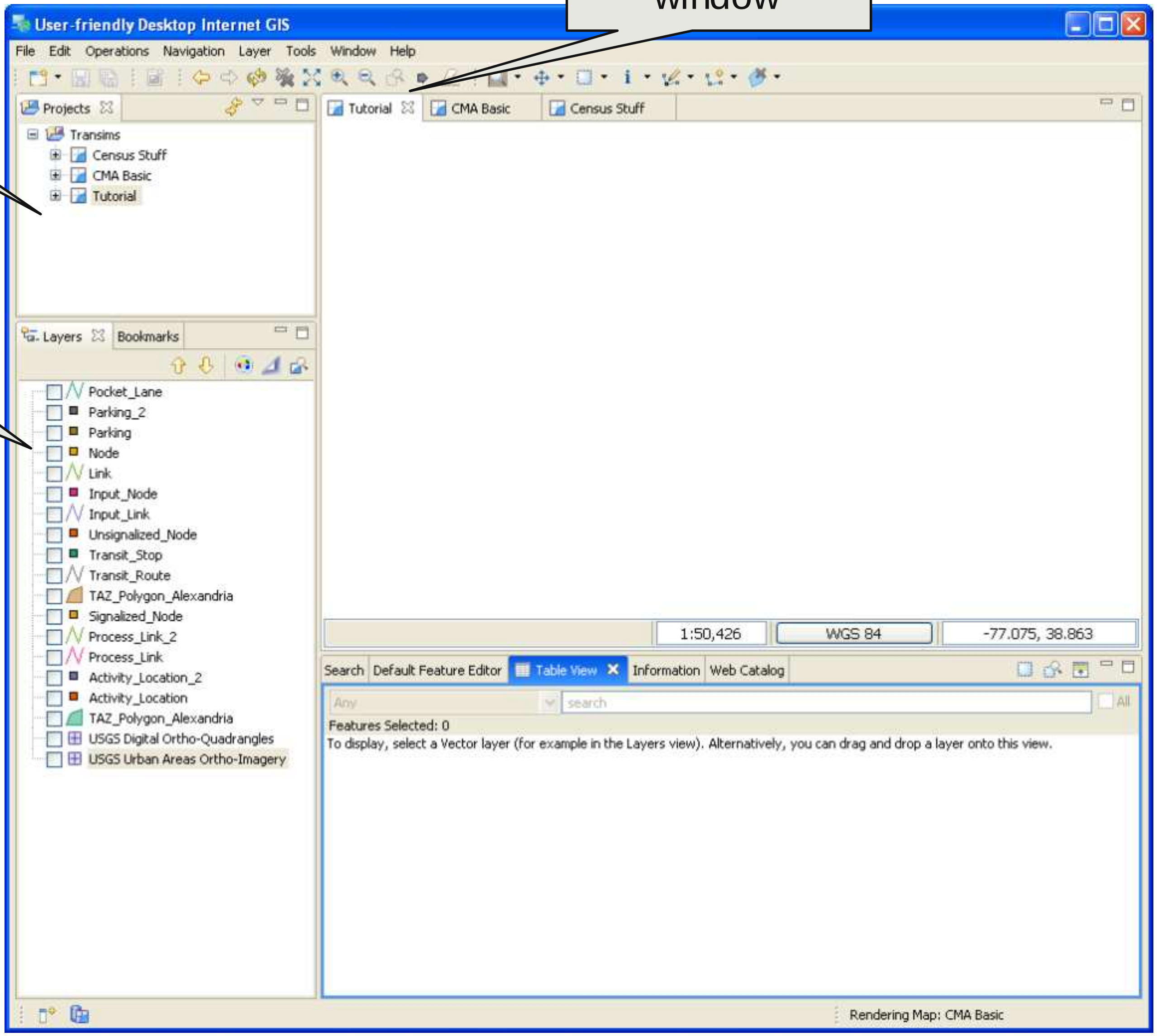
- Shape Files
  - Shape files are the most common GIS objects
  - The visual object data is stored in a ".shp" file
  - Database rows are stored in a corresponding ".db" file
  - A shape file is actually not a single file, but a collection of files with the same base name and different extensions:
    - *.shp, .db, .prj,.shx, and more*
- Map Service
  - There are a few web mapping services and standards
  - These provide satellite imagery and similar raster data
- Databases
  - GIS applications can connect to databases
    - *Oracle Spatial, PostGIS, and more*
- Additional standards are evolving

GIS uDig Tutorial

Project and map list

List of available layers (none selected)

Current map window



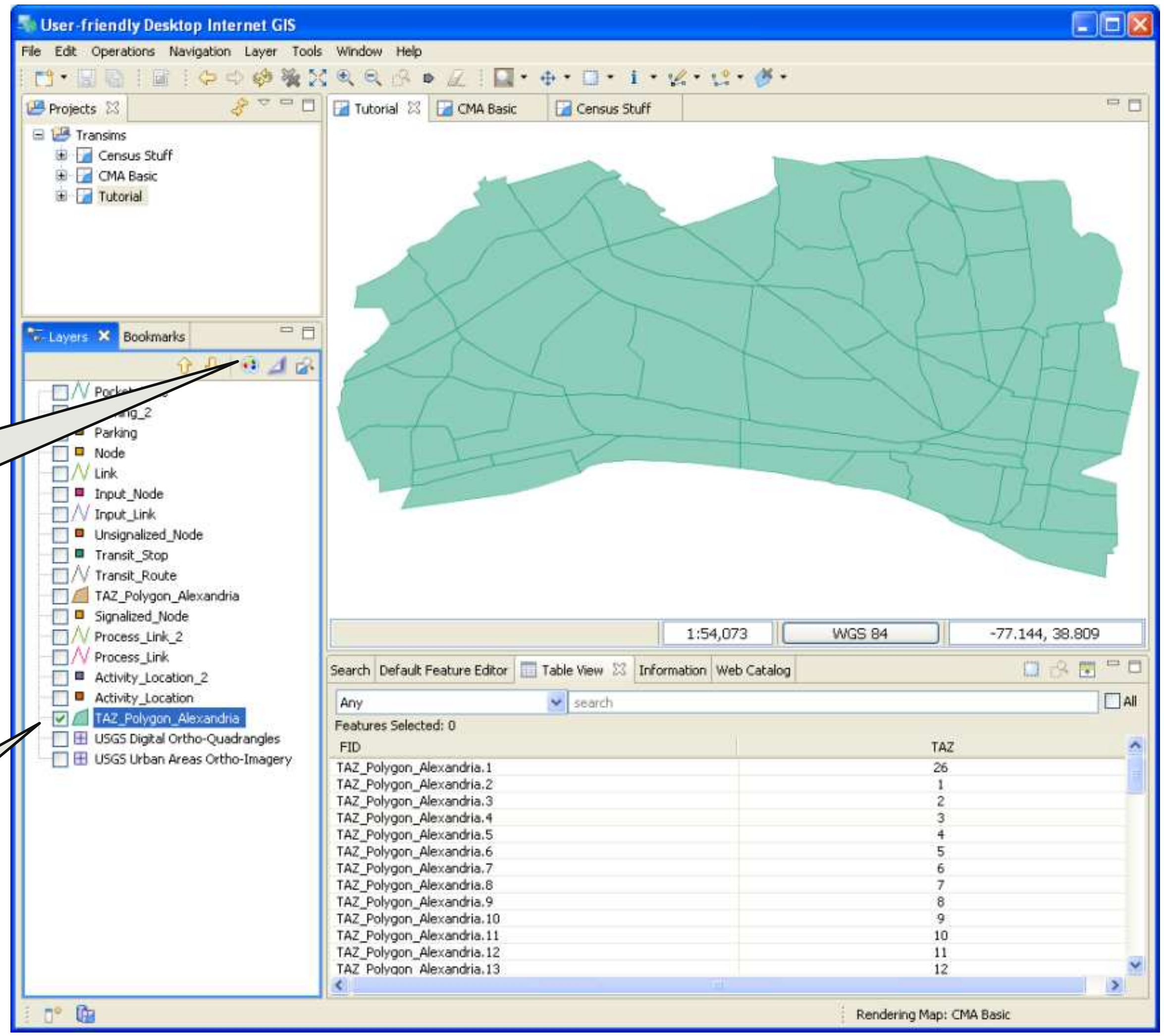
- Install uDig
- Open work space
- Create a project
- Create a map
- Add data layers from Alexandrian study (drag shape files into map window)

GIS uDig Tutorial

- Layers can be turned on and off by clicking in the small square boxes

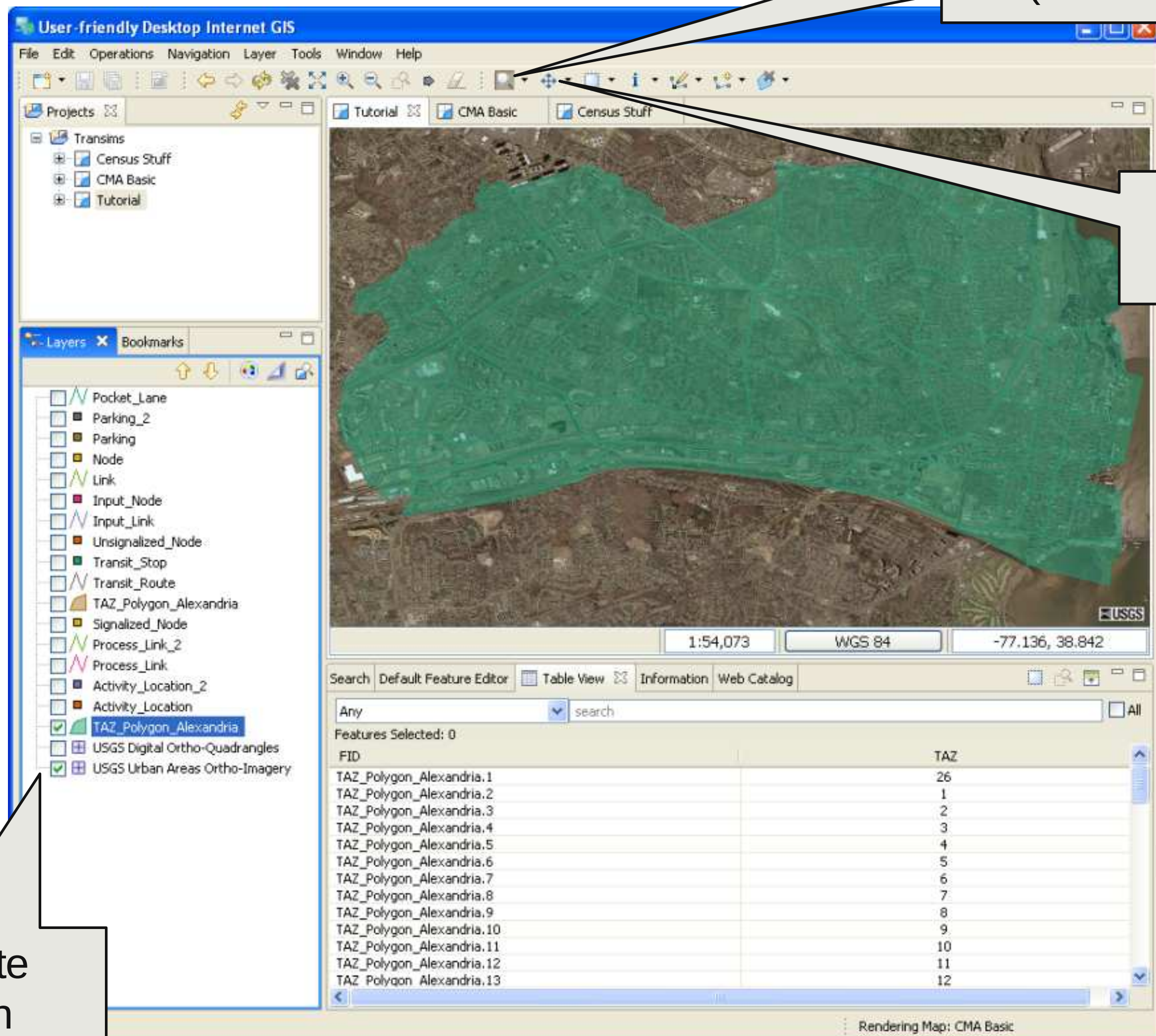
The palette allows setting properties for displaying the currently selected layer

Traffic analysis zones have been selected (zoom to layer if necessary)



GIS uDig Tutorial

Click here to change to zooming mode (wheel mouse?)

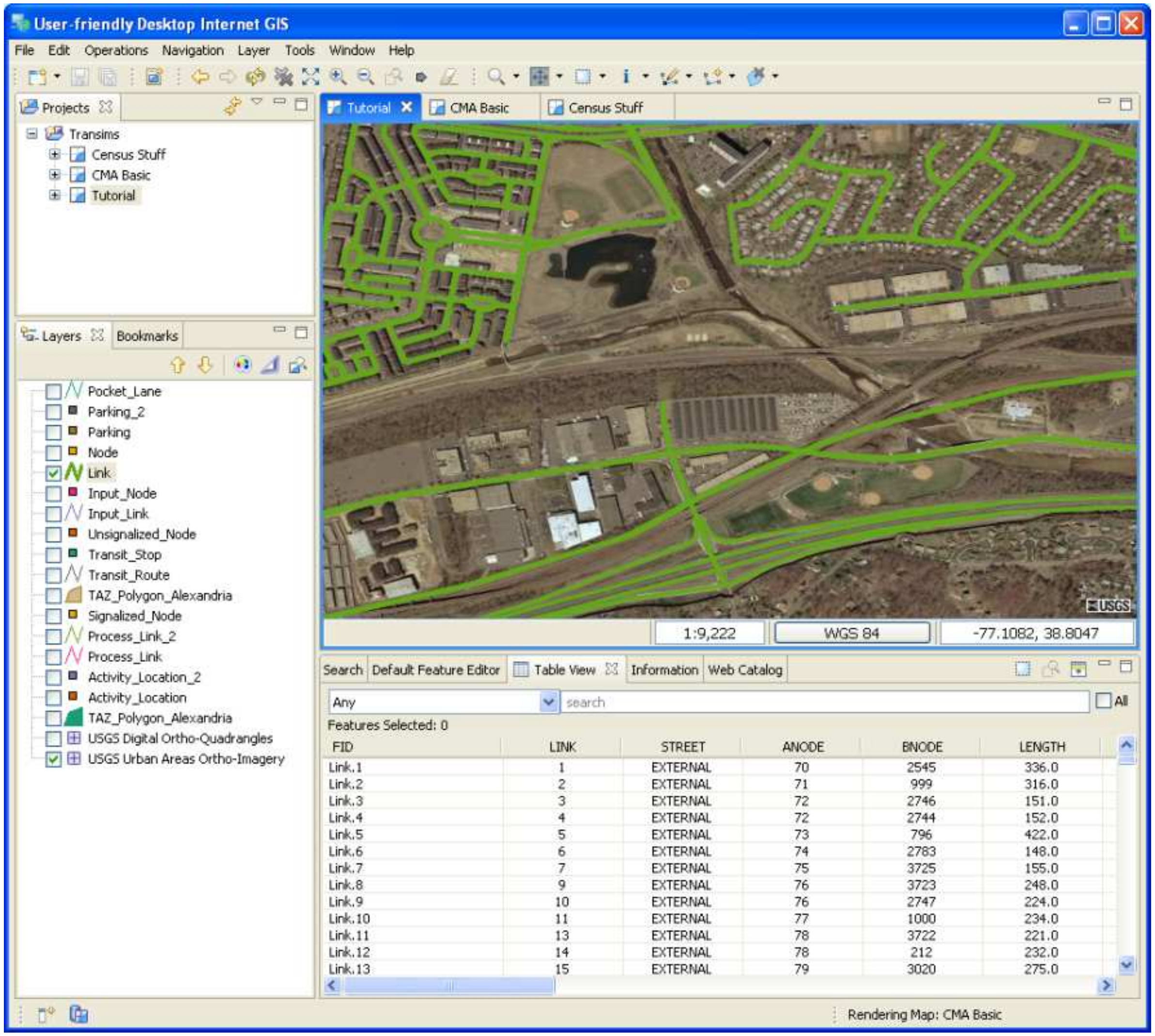


Click here for panning mode

Turn satellite imagery on

GIS uDig Tutorial

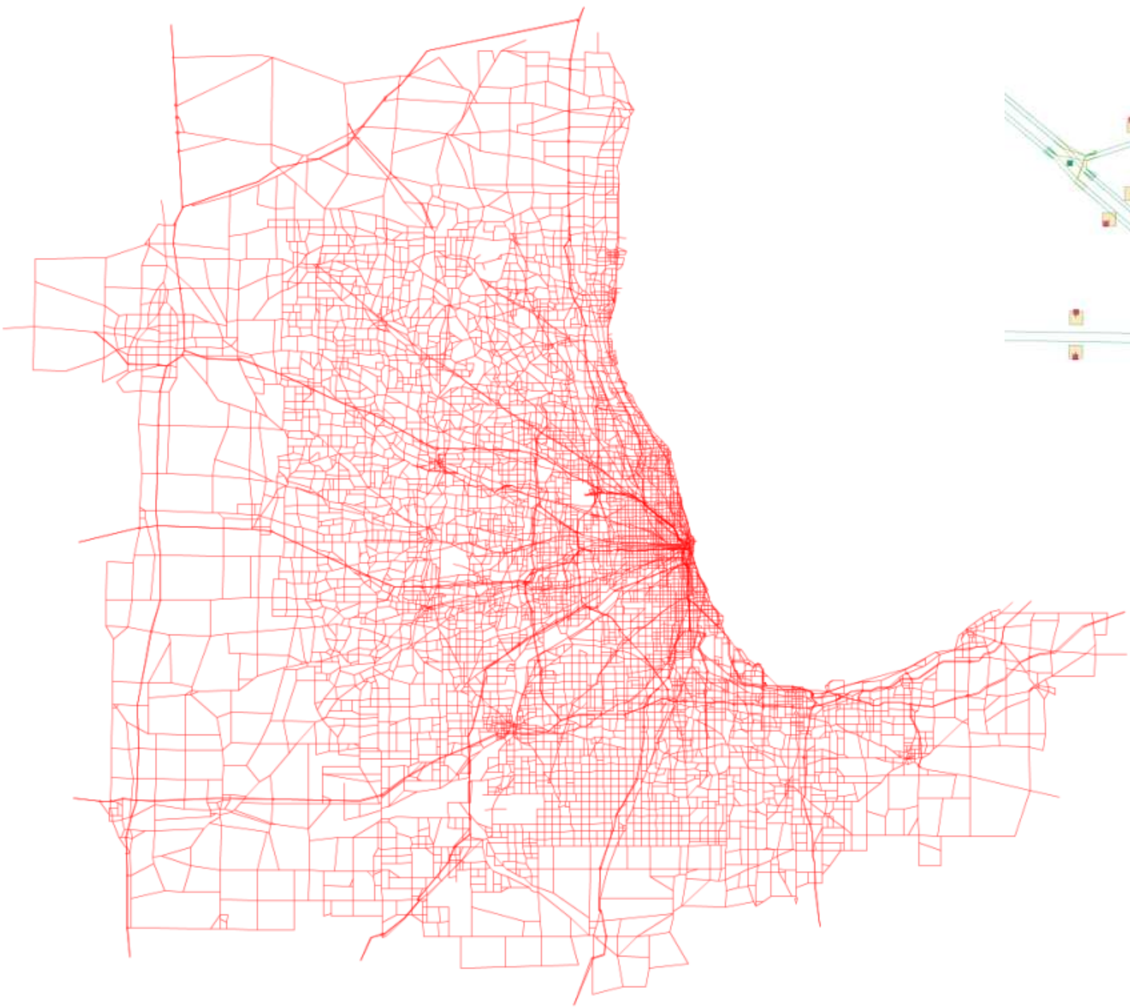
- Zoom in to a small area for more detail
- Turn the traffic analysis zones off
- Turn links on
- Change the properties to thick lines (size 3) and light green color

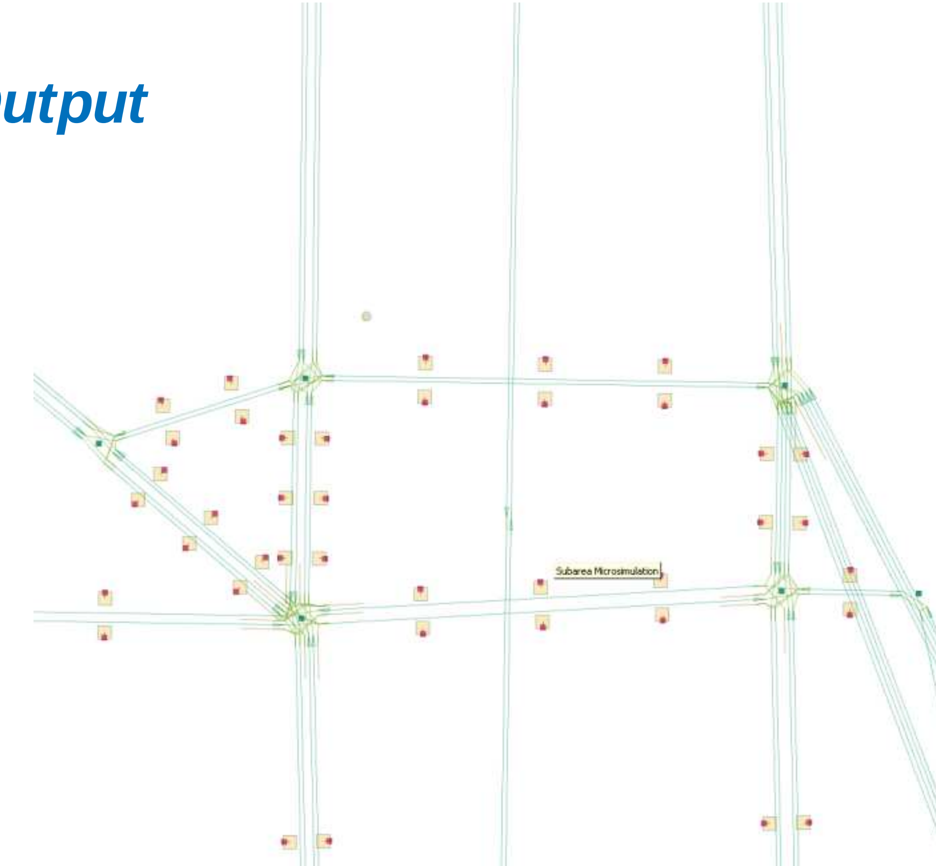


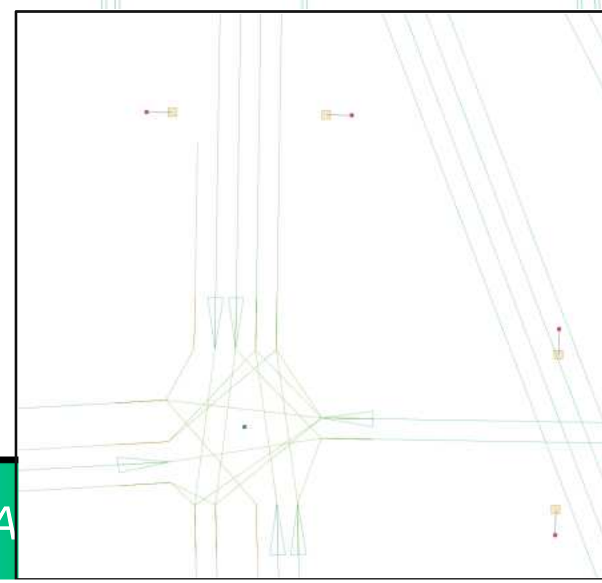
Part 2

GIS Tools in TRANSIMS

TRANSIMS Tools – GIS Layer Output







TRANSIMS Tools – GIS Layer Output

- **ArcNet:**
  - Creates highly detailed GIS shape files for links, nodes, and most other network features for visualization in ArcGIS (see previous slide)
  - Many configuration options to show individual lanes, activity locations, parking lots, and much more
  - Typical Control File:

NET_DIRECTORY	../../network/production
NET_NODE_TABLE	FullArea_Node
NET_LINK_TABLE	FullArea_Link
NET_ACTIVITY_LOCATION_TABLE	FullArea_Activity_Location
NET_PARKING_TABLE	FullArea_Parking
NET_PROCESS_LINK_TABLE	FullArea_Process_Link
NET_POCKET_LANE_TABLE	FullArea_Pocket_Lane
NET_UNSIGNALIZED_NODE_TABLE	FullArea_Unsignalized_Node
NET_SIGNALIZED_NODE_TABLE	FullArea_Signalized_Node
NET_LANE_CONNECTIVITY_TABLE	FullArea_Lane_Connectivity
NET_DETECTOR_TABLE	FullArea_Detector
NET_SHAPE_TABLE	FullArea_Shape
NET_ZONE_TABLE	FullArea_Zone
NET_LANE_USE_TABL	FullArea_Lane_Use
ARCVIEW_DIRECTORY	../../network/arcview

INPUT_COORDINATE_SYSTEM	UTM, 16N, METERS
INPUT_COORDINATE_ADJUSTMENT	0.0, 0.0, 1.0, 1.0
OUTPUT_COORDINATE_SYSTEM	UTM, 16N, METERS
OUTPUT_COORDINATE_ADJUSTMENT	0.0, 0.0, 1.0, 1.0

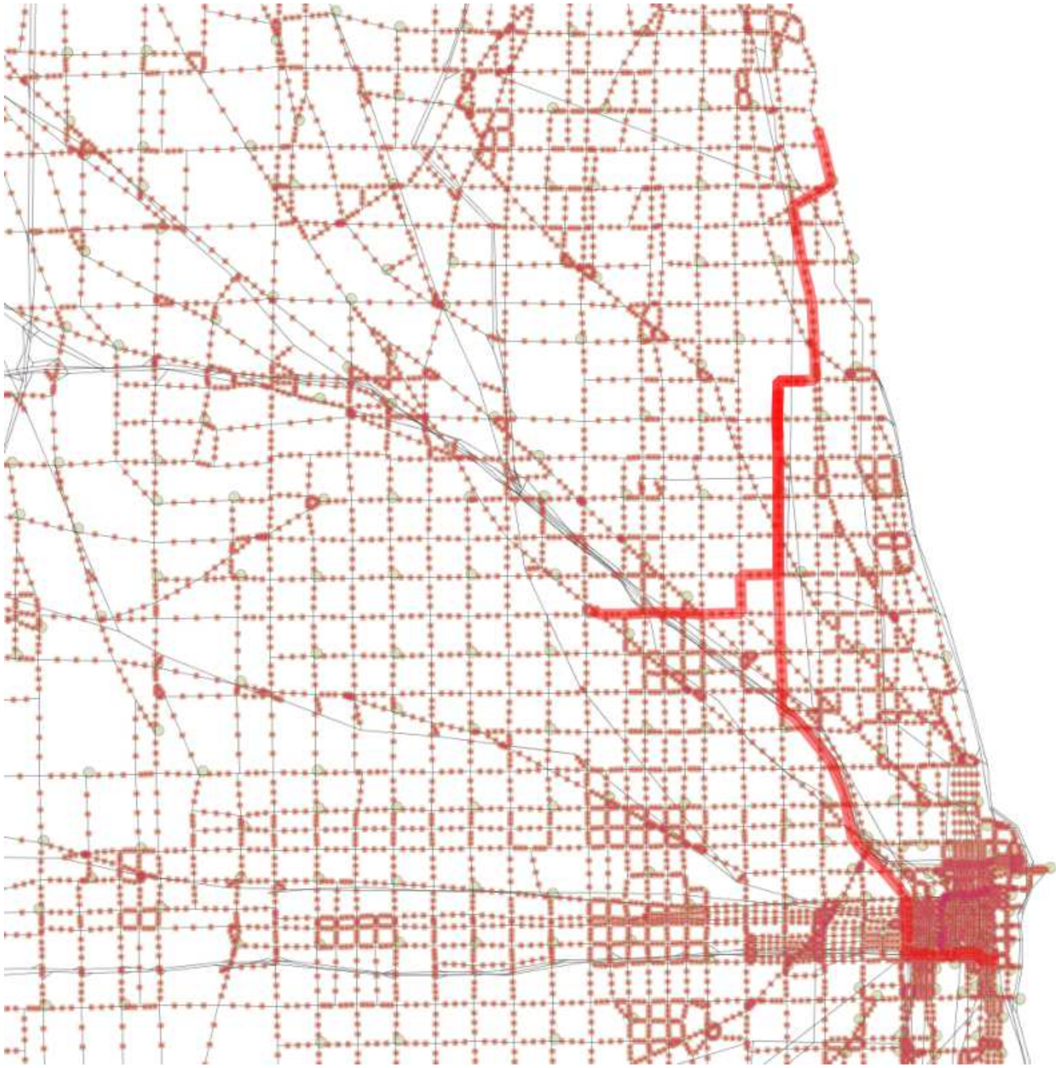
DRAW_NETWORK_LANES	TRUE
CENTER_ONEWAY_LINKS	FALSE
LANE_WIDTH	4.0
LINK_DIRECTION_OFFSET	5.0
UNSIGNALIZED_NODE_SIDE_OFFSET	0.0
UNSIGNALIZED_NODE_SETBACK	15.0
DRAW_ONEWAY_ARROWS	TRUE
ONEWAY_ARROW_LENGTH	10.0
ONEWAY_ARROW_SIDE_OFFSET	1.5
POCKET_LANE_SIDE_OFFSET	4.0
PARKING_SIDE_OFFSET	15.0
ACTIVITY_LOCATION_SIDE_OFFSET	20.0

TRANSIMS Tools – GIS Layer Output

ArcPlan:

Show individual plans or groups of plans in form of lines on the road and transit network (after routing)

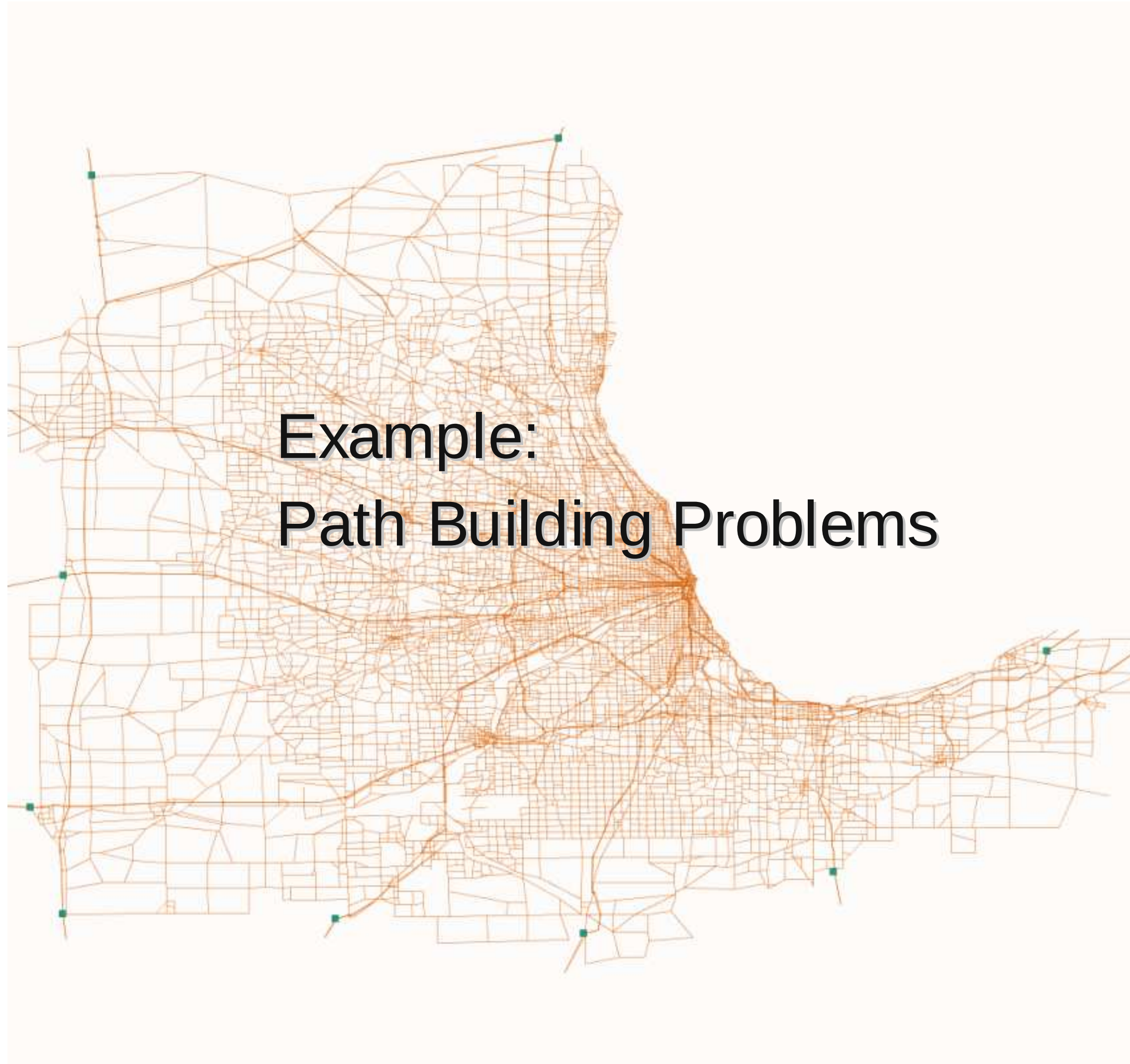
- Selection by:
  - Link list
  - Traveler list
  - Time interval
  - …
- Tight selection criteria are necessary to keep the number of plans reasonably small



TRANSIMS Tools – GIS Layer Output

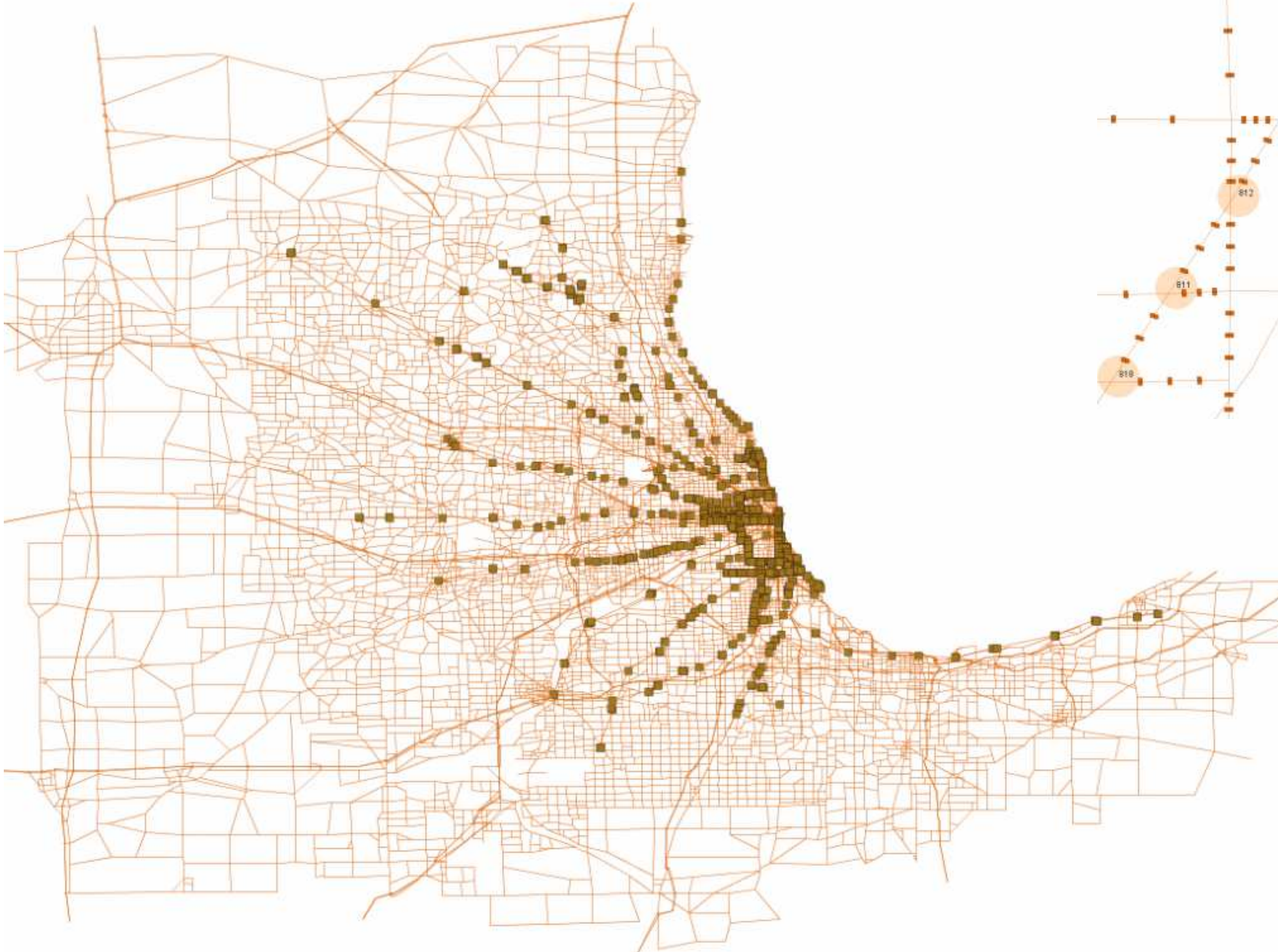
ArcProblem:

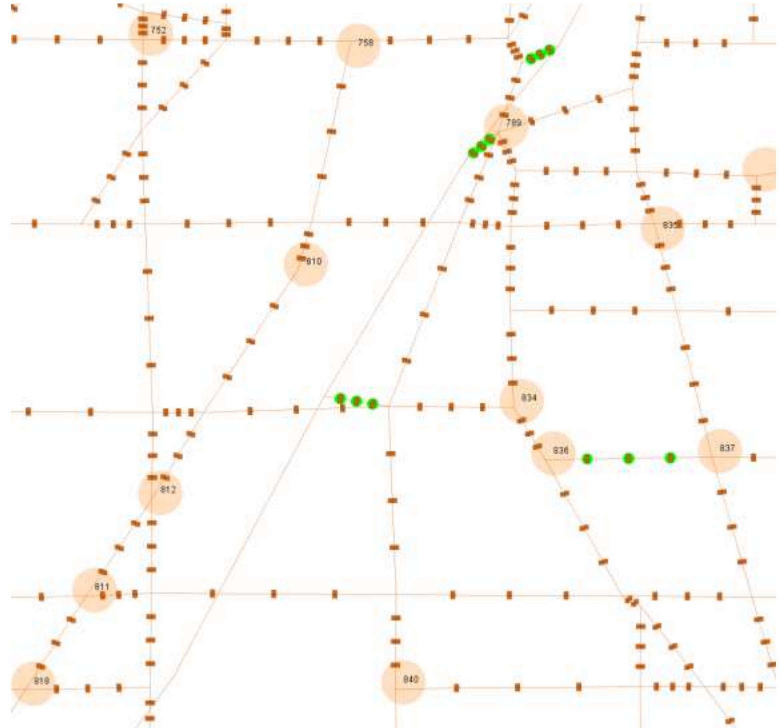
- Visualize the location of different problem types, such as:
  - Zero Node Problem
  - Access Problem
  - Circuity Problem, etc.
- Works both for router and microsimulator
- Helps with fixing the network as well as trip allocation



TRANSIMS Tools – GIS Layer Output

ArcProblem

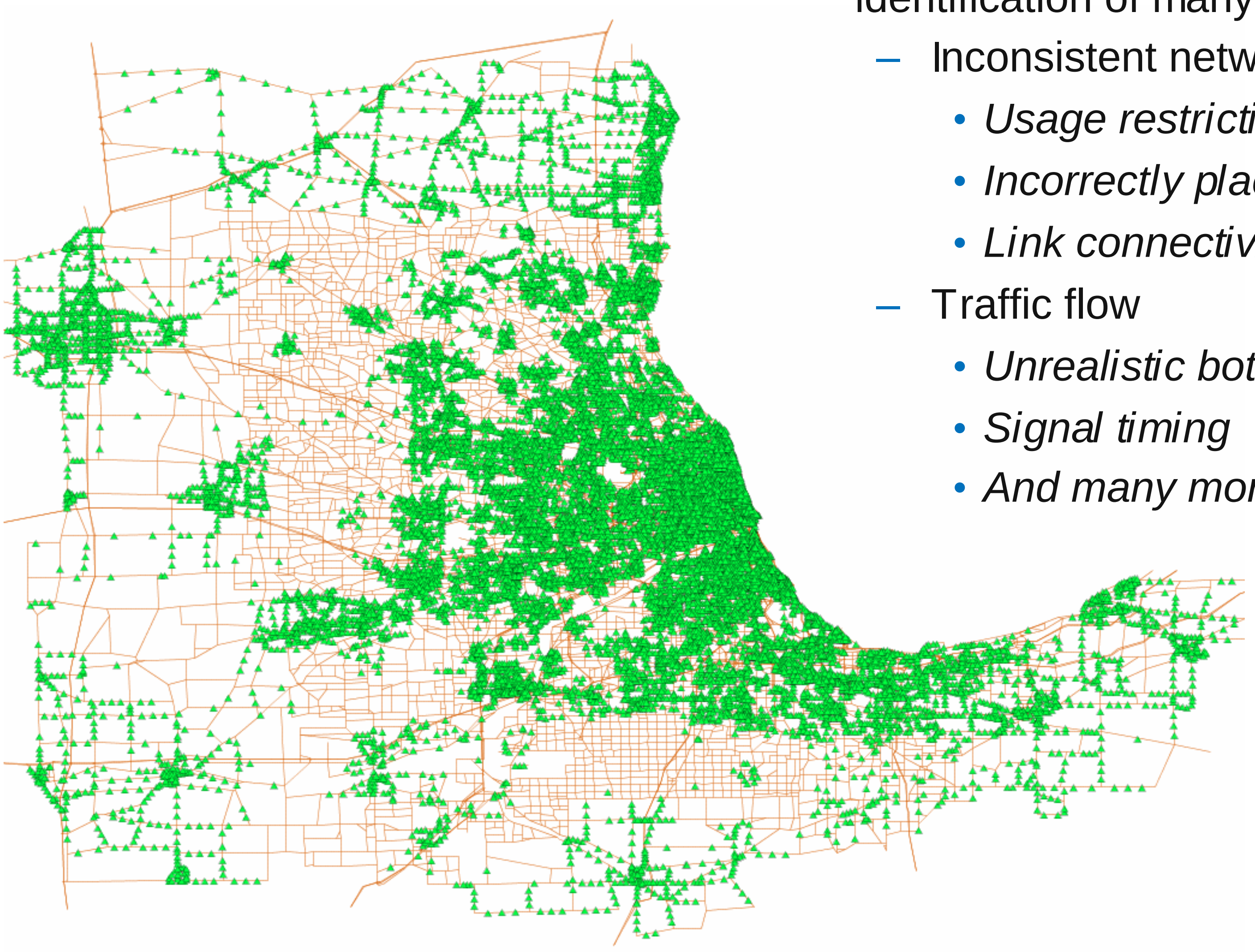




Example:

Access Problems

Network Cleaning



- Plotting of problems from both the router and the microsimulator allows for the identification of many problems, such as
  - Inconsistent network coding
    - *Usage restrictions*
    - *Incorrectly placed signals*
    - *Link connectivity*
  - Traffic flow
    - *Unrealistic bottlenecks*
    - *Signal timing*
    - *And many more …*

ArcProblem Sample Control File

- #
- # Coordinate system reprojection
- #
- INPUT_COORDINATE_SYSTEM UTM, 16N, METERS
- INPUT_COORDINATE_ADJUSTMENT 0.0, 0.0, 1.0, 1.0
- OUTPUT_COORDINATE_SYSTEM UTM, 16N, METERS
- OUTPUT_COORDINATE_ADJUSTMENT 0.0, 0.0, 1.0, 1.0
- #
- # Input and Output files
- #
- PROBLEM_FILE ../../router/00_problems
- ARCVIEW_PROBLEM_FILE ../../network/arcview/Router_PATH_BUILDING.shp
- #
- # TRANSIMS network files to be used as input for this run
- #
- NET_DIRECTORY ../../network/production
- NET_NODE_TABLE FullArea_Node
- NET_LINK_TABLE FullArea_Link
- NET_SHAPE_TABLE FullArea_Shape
- NET_ACTIVITY_LOCATION_TABLE FullArea_Activity_Location
- #
- # Options
- # =======
- #
- SELECT_PROBLEM_TYPES PATH_BUILDING
- #
- # "TOTAL","PATH_BUILDING","TIME_SCHEDULE","ZERO_NODE","VEHICLE_TYPE",
- # "PATH_CIRCUITY","TRAVEL_MODE","VEHICLE_ACCESS","WALK_DISTANCE",
- # "WAIT_TIME","WALK_ACCESS","PATH_SIZE","PARK-&-RIDE_LOT","BIKE_DISTANCE",
- # "DEPARTURE_TIME","ARRIVAL_TIME","LINK_ACCESS","LANE_CONNECTIVITY",
- # "PARKING_ACCESS","LANE_MERGING","LANE_CHANGING","TURNING_SPEED",
- # "POCKET_MERGE","VEHICLE_SPACING","TRAFFIC_CONTROL","ACCESS_RESTRICTION",
- # "TRANSIT_STOP","ACTIVITY_LOCATION","VEHICLE_PASSENGER","ACTIVITY_DURATION"

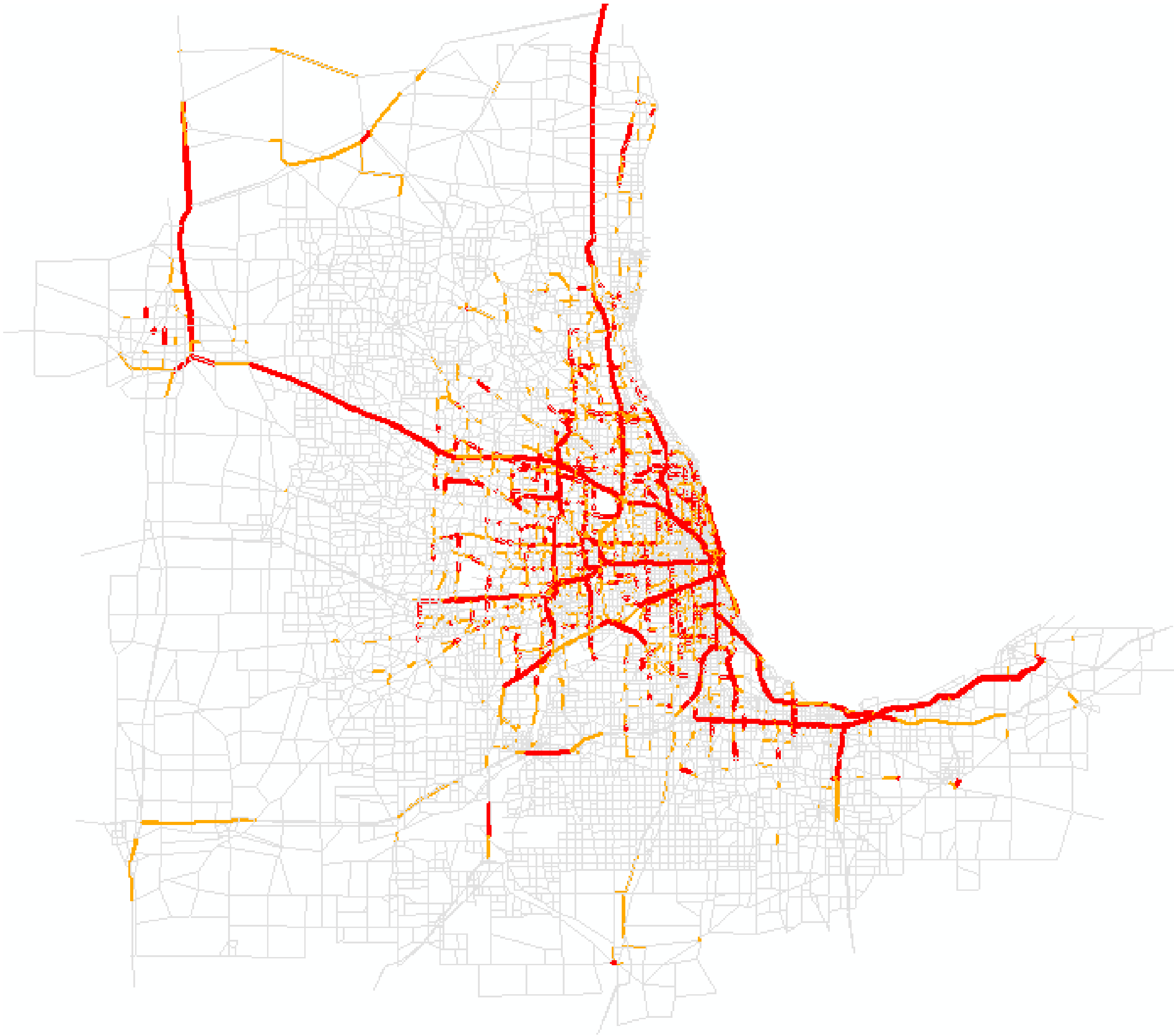
- # These options should be set to
- # the same values used ijn ArcNet
- #
- LANE_WIDTH 4.0
- CENTER_ONEWAY_LINKS FALSE
- #
- # This option creates little polygons pointing into
- # the direction of the problem instead of points
- #
- # DRAW_VEHICLE_SHAPES TRUE
- #
- # Other available keys ...
- #
- # PROBLEM_FORMAT
- # TIME_OF_DAY_FORMAT
- # SELECT_TIME_PERIODS
- # SELECT_TIME_INCREMENT
- # SELECT_LINKS
- # SELECT_SUBAREA_POLYGON

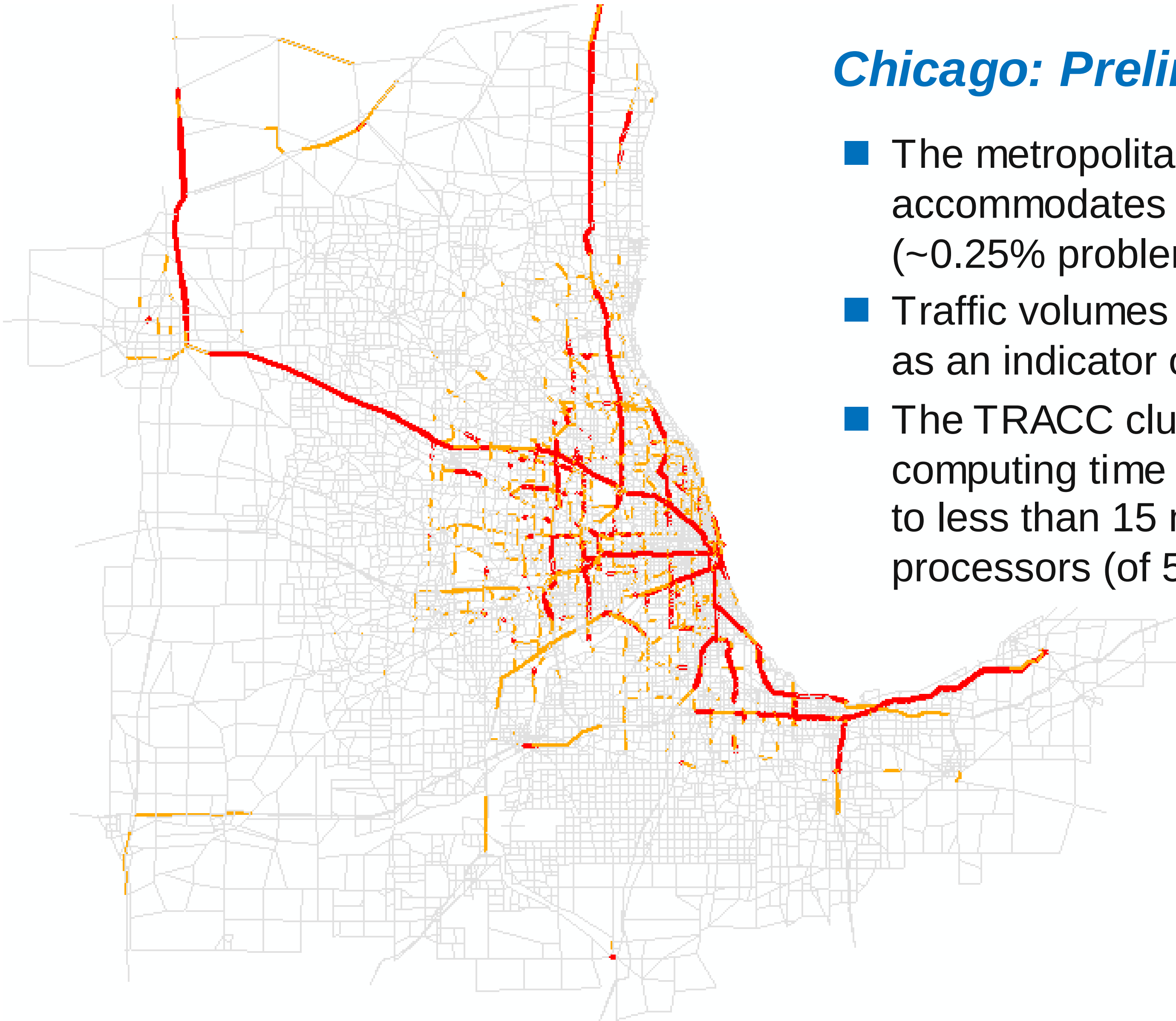
- ArcProblem works both with
  - Router
  - Microsimulator

TRANSIMS Tools – GIS Layer Output

ArcDelay:

- Visualize link delays, volumes, and similar link-related parameters by time intervals in form of GIS layers
- Next slide: animation of traffic volumes in 15 minute intervals for Chicago

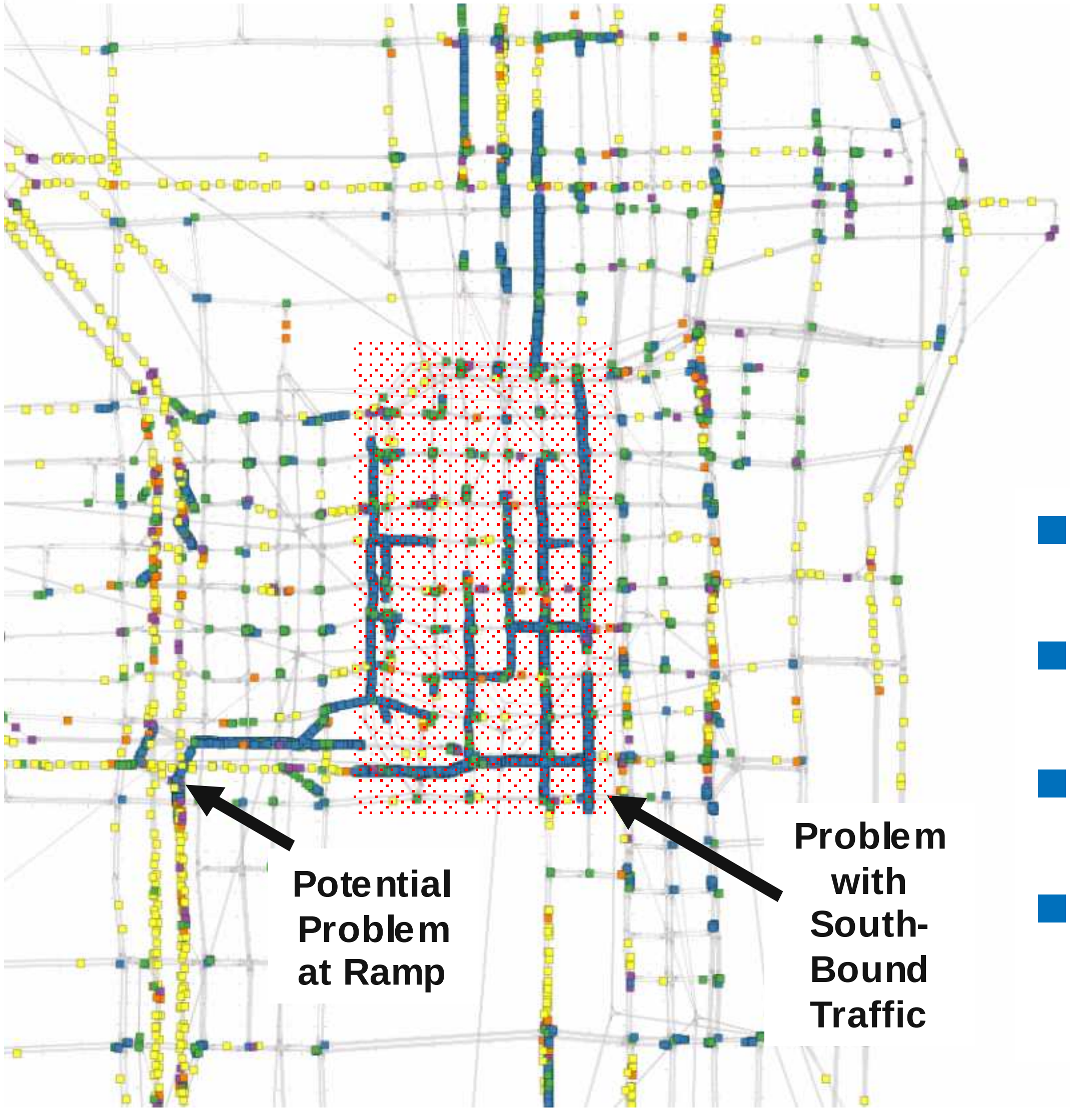


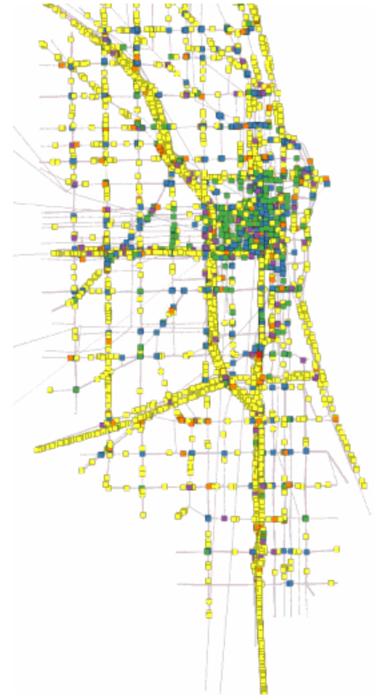


Chicago: Preliminary Results

- The metropolitan road network accommodates the trips very well (~0.25% problems)
- Traffic volumes per lane are shown as an indicator of congestion
- The TRACC cluster has reduced computing time for 27 million routes to less than 15 minutes using just 48 processors (of 512)

ArcSnapshot: Identification of Convergence Problems

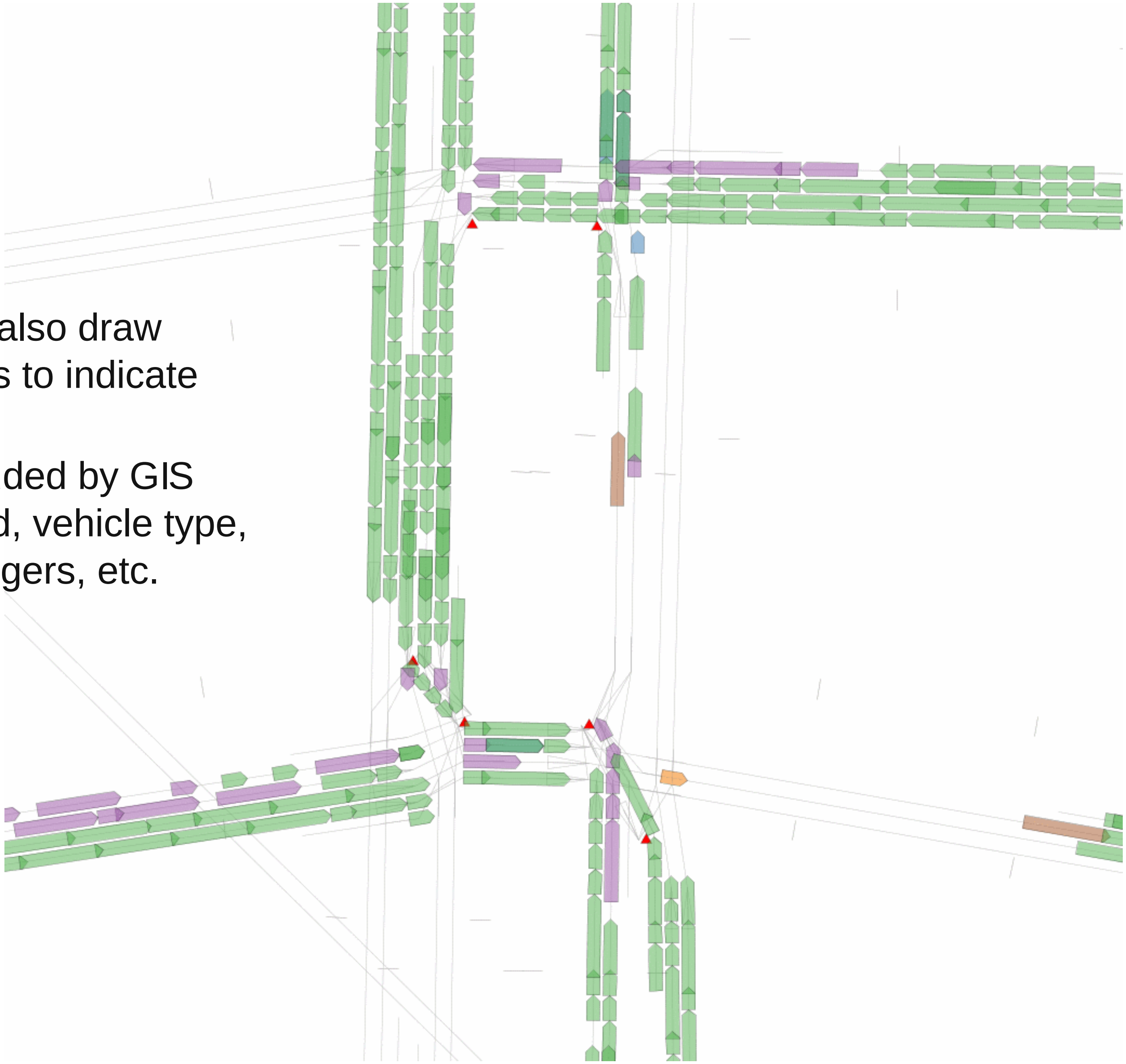




- ArcSnapshot creates a separate GIS layer for each time setp requested
- Time intervals can be chosen, at a specified interval to create layers
- A GIS polygon can be provided to select a specific area
- GIS software can use the attributes of the snapshot to plot color-coded symbols by speed, vehicle type, etc.

ArcSnapshot

- ArcSnapshot can also draw shapes of vehicles to indicate direction
- Color coding is added by GIS software for speed, vehicle type, number of passengers, etc.



TRANSIMS Tools – GIS Network Editing

GISNet:

- Reads ArcGIS node and link shape files and converts them into standard TRANSIMS network files
- The node file is used to adjust the location of the nodes
- The link file is used to introduce or edit shape points

- After running GISNet, the resulting TRANSIMS network files can be used to create a new set of ArcGIS shape files for a next iteration of editing

- **Note:** The GIS layers for nodes and links should be edited in separate steps to avoid inconsistencies. First, the node locations should be moved, then link shape points can be introduced or edited.
- **Note:** Link end locations are always dictated by the node locations, but link shape points become part of the link data.

Network Editing

- Move nodes
- Create shape points on links
- GISNet extracts geocoding into attributes

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