0RF 467

Transportation Systems Analysis

Fall2017/18

Class #10

Part 2: Planning and Analysis Tools of Transportation Demand and Investment

Traffic Assignment: Step 4 of the Classic Transportation Planning Process

Process by which trips (the demand side of transportation) are assigned to the various element of each of the available transportation services (the supply side). This process requires the modeling of the services offered by each available transportation technology. Graphs (aka Networks), made up of Nodes and Links (aka Arcs) are very often used as an efficient and effective data and analytical structure to represent the value and costs of various transportation technologies (the supply side). Some of the issue that we will be addressing:

- Major simplification: Constant link costs (linear networks):
  - "All-or-nothing" assignments
  - Multiple path assignments:
    - K-shortest paths
    - "Essentially-equal" shortest path
- Volume-dependent link costs
  - $\$_Q = \$_0 \{1 + a (Q / Q_{max})^b\}$

    where

    $\$_Q$ = link cost at traffic flow q

    $\$_0$ = "zero flow" link cost

    Q = traffic flow (veh/hr.)

    Q_{max} = practical capacity

    a , b are parameters

  Transportation Network Design

  - User-optimum assignments (important notes here. Please pay attention)
    - Wardrop's first principle: There exists no path that has a lower cost.
  - System-optimum assignments

Analytical Representations of Spatial Elements:

- Points (Nodes)
  - Location in "n"- dimensional space
  - Often 2-D; ex. Latitude, Longitude in some defined coordinate system such as WGS-84 ellipsoid overview; Detailed equations; Geodetic Databases; National Geodetic Survey (2cm accuracy objective) National Geospatial- Intelligence Agency
  - Other attributes of nodes: name, type, number
- Lines (Arcs (Links))
  - Defined by two (2) end points ("A"-node, "B"-node)
  - Attributes:
    - Distance: UTM Coord System (using a "ruler")
    - Name, speed limit, travel time, travel time distribution, …
- Polygons (Surface areas (often planar))
  - Defined by ordered closed sequence of directed arcs ("Closed Directed Walk")
  - Attributes: type, name, value,…
  - GeoTIFF (geographic referencing of TIFF file types)
- Volumes (Closed ensemble of surface areas)

Networks:

Definitions and notation:

Directed graphs and Networks: A *directed graph*, G = (N, A) consists of a set of N Nodes and a set of A arcs whose elements are ordered pairs of distinct nodes. A *directed network* is a directed graph whose nodes and/or arcs have associated numerical values.
Undirected graphs and networks: A directed graph with arcs having unordered pairs of distinct nodes.
Tails and Heads: A directed arc (i,j) has two end points i and j. We refer to i ("A" node) as the tail node and j ("B" node) as the head node. Arc (i,j) *emanates* from i and *terminates* at j. Arc (i,j) is incident to nodes i and j. It is *outgoing* from i and *incoming* to j. Whenever an arc $(i,j) \in A$, then node j is adjacent to i.
Degrees: The *indegree* of a node is the number on incoming arcs to that node and the *outdegree* is the number of its outgoing arcs. The *degree* of a node is the sum of the in- and out- degrees.
Adjacency list: The *arc adjacency list*, A(i) of a node i is the set of arcs emanating from that node. $A(i) = \{ (i,j) \in A : j \in N \}$. The *node adjacency list*, N(i) is the set of nodes adjacent to that node; $N(i) = \{ j \in N: (i,j) \in A \}$
Multiarcrs and Loops: *Multiarcs* are two or more arcs having the same tail and head nodes. A *loop* is an arc whose tail node is the same as its head node.
Subgraph: A graph G' = (N', A') is a *subgraph* of G = (N,A) if $N' \subseteq N$ and $A' \subseteq A$.
A graph G' = (N', A') is a *spanning subgraph* of G = (N,A) if N' = N and $A' \subseteq A$.
Walk: A *walk* in a directed graph is a subgraph of G containing a connected sequence of nodes (without any mention of arcs) or a connected sequence of arcs (without any mention of nodes).
Directed Walk: A *directed* walk is an "oriented" version of a walk in that any two consecutive nodes on the walk must be a member of the set of arcs $(i_k, i_{k+1}) \in A$.
Path: A path is a walk without any repetition of nodes. We can partition the arcs of a path into two groups : forward arcs and backward arcs. An arc (i,j) in the path is a *forward arc* if the path visits node i prior to visiting node j , and is a *backward arc* otherwise.
Directed Path: A *directed path* is a directed walk without any repetition of nodes. We can store a path easily by defining a *predecessor index*, *pred (j)* for every node j in the path.
Cycles: A *cycle* is a path $i_1 - i_2 - i_3 - \dots i_r - i_1$. Cycles can be directed.
Acyclic Graph: A graph is *acyclic* if it contains no cycles.
Connectivity: We will say that two nodes, i and j , are *connected* if the graph contains at least one path from node i to node j. A graph is *connected* if every pair of nodes is connected; otherwise it is *disconnected*.
Strong connectivity: A connected graph is strongly connected if it contains at least one *directed* path from every node to every other node.
Cut: A cut is a partition of the node set N into two parts, S and $\underline{S} = N - S$. Each cut defines a set of arcs consisting of those arcs that have one endpoint in S and the other in $\underline{S}$.
s – t Cut: This cut has node $s \in S$ ant $t \in \underline{S}$.
Tree: A *tree* is a connected graph that contains no cycles.
A tree of n nodes contains exactly n – 1 arcs.
A tree has at least two *leaf* nodes (nodes with degree 1)
Every two nodes of a tree are connected by a unique path.
Forest: A graph that contains no cycles is a *forest*. Alternatively, a forest is a collection of trees.
Subtree: A connected subgraph of a tree is a *subtree*.
Rooted trees: A rooted tree is a tree with a specially designated node called a *root*. Rooted trees are viewed as hanging from the root.
Directed-out-tree: every path from node s is a directed path