DEVELOPMENT OF A TRANSIT PASSENGER INFORMATION SYSTEM USING GIS

By
Dr. Ashish Verma
Transportation Systems Engg.
Dept. of Civil Engg.
Indian Institute of Technology Guwahati
Guwahati, Assam, India
E-mail: ashishv@iitg.ernet.in

Presentation at
Institute for Transportation Planning and Systems
Swiss Federal Institute of Technology Zurich

OVERVIEW

- Introduction
- Past Research
- Problem Definition
- System Architecture and Design
- Mathematical Formulation
- Summary and Further Work

INTRODUCTION

- Public transport modes are considered as efficient modes of transport because they carry more number of passengers per unit of space occupied.
- Due to spatial and temporal variations in roadway, traffic and weather conditions, travelers within cities are not generally conversant with the prevailing public transport schedules, routes and traffic conditions.

INTRODUCTION

- Historically, transit agencies have relied on printed routes and schedules to provide transit service information.
- Users have had to select routes and transfer points based on printed information, which could be complex and confusing.
- Updates of routes and schedules is not reflected timely on the printed brochure.
- Information given by customer service agents could be erroneous and inconsistent.
- Hence, manual process becomes; tedious, time-consuming, often error prone and inconsistent.

PASSENGER INFORMATION SYSTEMS

- Passenger Information Systems aim at bridging the information gap by providing the pre-trip and/or en-route information to the travelers about their travel options, so that they can take well informed travel decisions.
- Abdel-Aty (2001) performed a survey of the effect of advanced transit information and stated, "About 38% of non-transit users indicated that they might consider transit use if appropriate transit information was available to them".

PASSENGER INFORMATION SYSTEMS

- Passenger Information System (PIS)
  - Assist travelers by providing them timely, accurate, reliable and relevant information
  - Influence their travel behavior about mode choice, time of travel, cost of travel, route choice or trip making.

GEOGRAPHICAL INFORMATION SYSTEMS

- Geographical Information Systems (GIS) are a powerful tool for visualization, planning, operations, analysis, and maintenance across many areas and functions.
- Because of the spatial nature of transportation data, GIS is the perfect match. Using a base map and layered, geographically coded data, GIS provide a variety of spatial views and broad query capability.

Past Research on PIS

- **(Li and Kurt, 2000)**
  - Multi objective linear programming model
  - Multimodal and fixed route transit networks
  - Optimal path having least travel time and least waiting time
- **(Peng and Huang, 2000)**
  - Web-based transit information system design for single-mode network
  - Internet (GIS) technologies to integrate Web serving, GIS processing, network analysis and database management.
  - Optimal path having least travel time and least transfer time

Past Research on PIS

- **(Lozano and Storchi, 2001)**
  - Algorithm for obtaining the Shortest path in multimodal networks, based on travel and transfer time.
- **(Zografos and Madas, 2003)**
  - Consider the shortest path in terms of least time shortest path or least number of mode transfers or mode or route preference.

Shortcomings

- Shortest paths were generated primarily based on travel time and waiting or transfer time.
- Walking time and travel cost have not been given due importance in trip planning
- Most of the earlier approaches assume ubiquitous availability of service on every route and stop, resulting in erroneous trip plans. For the same route, not every segment of the route has the same amount of services all the time.

Shortcomings contd..

- Most of research focused on single mode network. Attempts with multi-modal system are very few.
- Different public transport modes with different characteristics and level-of-service makes the trip making problem much more complex.
- The concept of path viability in multi-modal network w.r.t. sequence of the used modes has rarely been attempted.
- Individual user's choice in terms of maximum acceptable modal transfers, journey through a mandatory intermediate destination etc. have not been incorporated in the past.

GENERALIZED COST

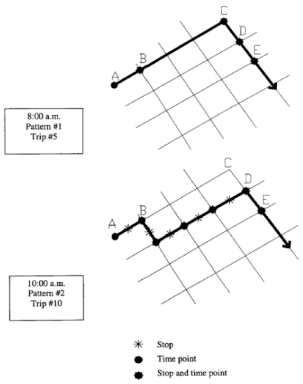
- The generalized cost of trip making is referred to as the sum of the direct money outlays and the time used in making trips, expressed in monetary terms.
- The monetary time-coefficient for every leg of the trip is calculated, depending on the user characteristics.
- For example, a disabled person might perceive walking time at terminals as uncomfortable and would associate a higher cost factor for the walking time.

GENERALIZED COST AS A PARAMETER

- An assumption that users are simply aiming to minimize their money costs, when in fact they attach great significance to time saving, may lead to serious errors in trip planning.
- This consideration is especially important in the Indian scenario, where the various modes of transport are not harmonized, and the transfer time from one mode to another may be very large.

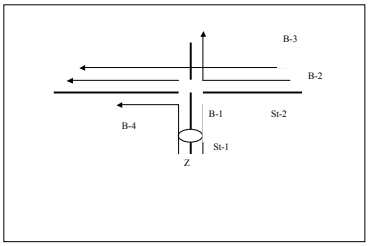
Difference Between Transit and Highway Network

- Transit service is time dependant. The availability and the level of transit service vary by time of day and day of week. (Figure)
- For the same route, not every segment of the route has the same amount of services all the time. Some stops lack service during some times of the day and some days of the week. *(peak/off-peak, express/limited, weekday/weekend services)*.
- Hence, integration of transit routes and temporal transit services is necessary.



Difference Between Transit and Highway Network

- One bus stop may serve multiple routes, and more than one transit route may share the same street links. Hence, trip planning system requires a relational database linking bus stops, transit route, and street network. (Figure)
- Not every bus stop has a scheduled arrival and departure time (time point). Hence, for trip planning the location of buses at specific times has to be estimated.
- **These unique features make the minimal path finding application for transit networks much more challenging.**



Multimodal viable path

- Generalized cost includes travel time as well as cost of changing the mode.
- Each user assigns a personal cost to each modal change.
- He/she prefers the shortest path with no more than a predefined number of modal transfers

Multimodal viable path (Contd..)

- Multi-modal viable path problem is one of the important problems in urban transportation, and its solution is specially useful during rush hour.
- It is not easy to use private vehicle from home in outskirts to working place in downtown.
- Metro network is scattered and doesn't arrive everywhere, but bus network is thick and arrives almost everywhere.
- Since, metro network is connected and its transboards are made easier to user, then a metro user uses it as long as possible in his/her path.

Multimodal viable path (Contd..)

- Also, user could have "illogical paths", as when the bus is taken after the metro to be again followed by the metro. (Figure)
- Such illogical paths seems an unlikely choice for an user, however that path could be the shortest path solution.
- We consider that user does not choose such a path, and is eliminated from any consideration of the feasible path sets.
- **Hence, a viable path is the one that respects a set of constraints on its sequence of used modes and does not include more than a predefined number of modal transfers.**

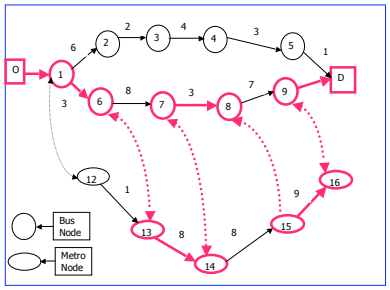


Figure: Example Multi-modal Network

PROBLEM DEFINITION

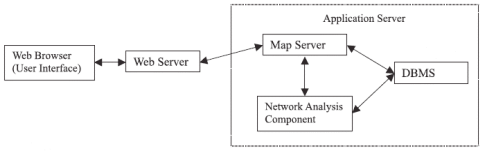
- Develop a web-based Transit Passenger Information System, which takes into account:
  - Generalized Cost approach
  - Multi-objective user queries
    - Time of arrival and departure
    - Maximum number of modal transfers
    - Maximum walking distance

    Along with one of the basic choices:
    - Optimum path based on generalized cost
    - Minimum time
    - Minimum cost

SYSTEM ARCHITECTURE AND DESIGN

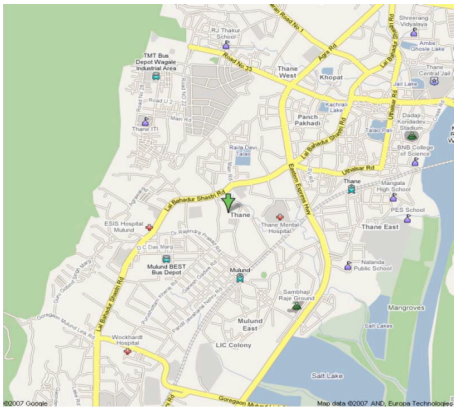
- Three-tier architecture
  - Client tier
    - Web browser
  - Server tier
    - Web server
  - Application tier
    - Map server
    - Network analysis
    - DBMS

THREE TIER ARCHITECTURE



MAP SERVER DESIGN

- Google Maps (GMap) provide a very high level of detailing, and their Application Programming Interface (API) allows users to create custom HTML pages using JavaScript.
- Thus, the spatial data of the network in concern is pre-loaded onto the GMap server.
- The transit network, is loaded onto MapInfo and the two networks are geographically synchronized.



MAP SERVER DESIGN

- The point-and-click capability of custom GMap applications is utilized to create an interactive map interface, which provides users a map interface to select locations directly on the map.
- Thus, the basic map rendering functions by the user are carried out on the GMap interface.
- The consequent (Latitude, Longitude) of the origin and destination isolated by the user are piped to MapInfo for network analysis.

DATA AND DBMS

- Street spatial data (streets, landmarks etc) stored in the GMap server.
- Transit spatial network (point feature) is loaded onto MapInfo.
- Temporal data (bus schedules etc) are stored in (.TAB) files which can be handled by MapInfo.

NETWORK ANALYSIS

Steps followed:

- All transit nodes that are within walking distance (a max of 500 m) of the user's trip origin and destination are found and flagged.
- Travel time calculation:
  - In-vehicle time
  - Walking time
  - Waiting time
  - Transfer time

NETWORK ANALYSIS

- Generalized Cost Calculation
  - Cost-per-unit-time's for the four time segments are calculated on the basis of the weightages input by the user.
  - Algebraic sum of fare and monetary equivalents of the time segments is assigned to each possible path.
- Multimodal Viable Path
  - A user may not like to execute more than a certain number of modal transfers.
  - A user may like to use rapid transit for as long as possible in his path.
  - Illogical paths – say, a bus is taken after the metro to be again followed by the metro mode. It is an unlikely choice for a user, hence these are removed.

MATHEMATICAL FORMULATION

- Shortest Path Tree:
  - Let $G = (N, A)$ be a directed graph, where N and A are, respectively the sets of nodes and arcs.
  - The shortest viable path problem is to find a directed tree T rooted at o such that the path to i is the shortest path from o to i $\forall$ $i \in N$ connected to o.
  - Let P be a path from o to d. Given a node j, the forward star and the backward star of j are denoted, respectively by $FS(j)=\{(j, i) \in A\}$ and $BS(j) =\{(i, j) \in A\}$

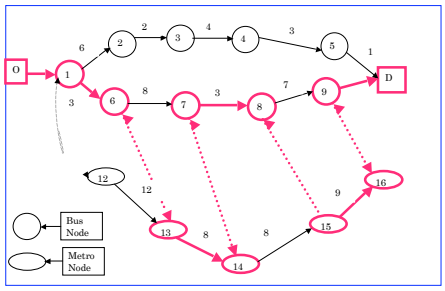
SHORTEST PATH TREE

- $N_j^+ = \{i \in N : (j,i) \in A\}$ and $N_j^- = \{i \in N : (i,j) \in A\}$ denote the sets of nodes connected to j by $FS(j)$ and $BS(j)$ respectively.
- The sets of nodes and arcs are respectively denoted by N_r and A_r, where r ($r \in$ *Bus, Metro, Transfer*) stands for a travel or transfer mode. If r indicates a modal transfer, N_r is empty and A_r includes all the transfer arcs.

SHORTEST PATH TREE

- A *mono-modal path* is a path composed of nodes belonging to the same N_r set.
- A *subpath* is a monomodal path, which is a subsequence of a path. The first node is called *initial node*, and the last one, *ending node*.
- A *maximal mode-r-subpath* is a subpath formed by nodes belonging to N_r, where the initial and the ending nodes are adjacent to nodes belonging to other sets.
- A path from o to d is a *viable path* if it does not include more than one *maximal metro-subpath*, and also the modal transfers are less than k.

EXAMPLE MULTI-MODAL NETWORK



SHORTEST PATH TREE

x_{ij} = {1} if arc $(i,j) \in A_r, r \in M$ is used,
= {0} otherwise

y_j = {1} if metro mode is used up to node
= {0} otherwise

t_{ij} = Travel Time of arc (i,j)

c_{ij} = Cost of arc (i,j)

SHORTEST PATH TREE

Objective Function:

$$\text{Min } Z = w_1 t^{wk}_{o,d} + w_2 t^{wt}_{o,d} + \sum (w_3 t^{tr}_{i,j,r} + c_{i,j,r}) x_{i,j} + w_4 \sum t^{tt}_{i,j} x_{i,j}$$

Subject to:

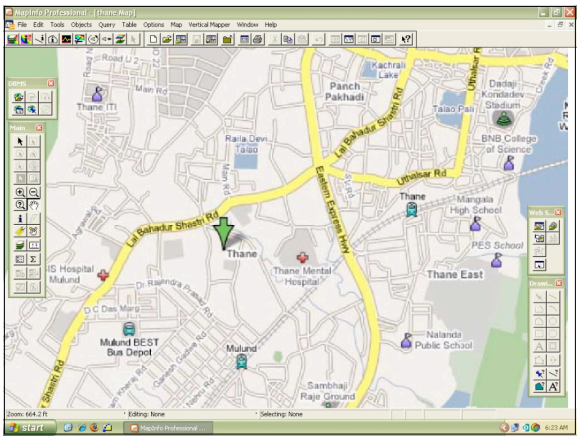
- $g_1 = \sum x_{ij} - \sum x_{ji} = \begin{cases} -1 & if\ \ j = o \\ 0 & \forall\ \ j \in N, j \neq o,d \\ 1 & if\ j = d \end{cases}$
- $g_2 = y_j - y_i + x_{ij} \leq 1 \forall (i,j) \notin A_m$

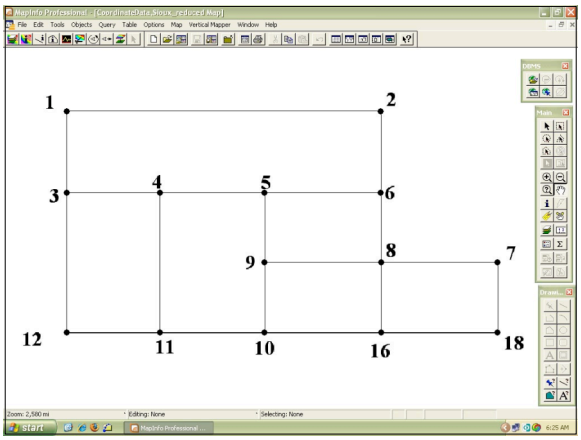
SHORTEST PATH TREE

- $g_3 = y_j - y_i - x_{ij} \geq -1 \forall (i,j) \notin A_m$
- $g_4 = y_j - y_i + x_{ij} + \sum_{l \in N_{im}} x_{li} \leq 2 \forall (i,j) \in A_m$
- $g_5 = y_j - y_i - x_{ij} + \sum_{l \in N_{im}} x_{li} \geq 0 \forall (i,j) \in A_m$
- $g_6 = \sum_{(i,j) \in A_t} x_{ij} \leq k$
- $g_7 = a^k{}_i - d^k{}_i - t \leq t^{wt}{}_{max}$

SUMMARY

- The design incorporates elements of
  - Web serving
  - GIS processing
  - Network analysis
  - Database management
- A custom application of GMap to perform basic Latitude-Longitude queries and walking distance calculations has been built.
- The network of Thane has been imported in MapInfo and geographically referenced.





FURTHER WORK

- The application server of the system architecture proposed, has to be created using MapBasic.
- The mathematical formulation for the shortest path tree has to be implemented.
- The web server and application server of the system architecture will be integrated in an HTML-MapBasic framework.

Namaste

Thank you

Danke (schÖn.)