GIS framework for Taluka Bus Transportation Analysis and Provisioning

under guidance of
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Presented by
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Contents

● Development Analysis:
  MSRTC and Other service providers
  Understanding the working of PRI and People’s expectation
  **ICT based interventions for Transportation**

● Framework Development
  Digital Geography, Methodology for its creation and Integration with Census

● Analytic Tools
  Socio-economic parameters , Operational data and Migration of data into a database
Transportation as a Carrier of Development
What is Development?

- Development” can be defined roughly as “an event constituting a new stage in a changing situation” implicitly a positive/desirable event[1]
- Sadak, Bijli, Pani for all with high predictability, reliability, high accessibility for all
- Highly interdisciplinary, transdisciplinary

[1] [Development and Development Paradigms-FAO]
Maharashtra State Road Transport Corporation

- State Transportation Undertaking with 18710 Buses, 609 bus stands and 250 Bus depots[2]
- Motto ‘जनसामान्यांसाठी ... रस्ता तिथे एस. टी.’
- 31 divisional offices
- Depot-wise, Division-wise, Region-wise information analysis [3]:
  i) Geographical Information System
  ii) Graphical Reports
  iii) Vehicle Monitoring System
  iv) 20 Point and Budget
  v) Daily Report

MSRTC counts its losses

KOLHAPUR: The state transport corporation is finding it difficult to stay on course with a cumulative net loss of Rs 2712 crore in last five years. The Maharashtra State Road Transport Corporation (MSRTC) is one of the largest public

PUC panel reports points out MSRTC's losses, blames e-ticketing system

The report was filed by a legislative committee led by Bhartiya Janata Party MLA Sunil Deshmukh.

State Transport Minister Diwakar Raote on Monday urged Chief Minister Devendra Fadnavis to waive State taxes on diesel for the Maharashtra State Road Transport Corporation (MSRTC).

Mr. Raote said the steady rise in the prices of diesel had severely affected the MSRTC and has threatened to affect the payment of salaries of its employees.

Mr. Raote in his letter to the Chief Minister said that the rising fuel prices had increased the financial burden on MSRTC by ₹400 crore every year.

Fare hike on cards

He said that the MSRTC was also mulling over hiking the fares to tackle the increasing cost of fuel. Abhijit Bhosale, spokesperson for MSRTC, said the details of the fare hike were yet to be worked out.

MSRTC officials said diesel prices were at ₹58.02 per litre in May 2017, but have now increased to an average of ₹68.39 per litre across the State. The officials said that they would also have to factor in a wage revision for the MSRTC's one lakh employees.

Rising fuel prices has increased the MSRTC's budget by at least Rs 460 crore annually. A salary hike offered to its employees also put a burden of Rs 4849 crores on the corporation.


Information and Communication Technology (ICT) in the road transportation sector to mitigate with the following challenges:

1. Good quality data to support evidence-based policy making
2. Increase in efficiency of the road transport system and satisfaction of its users
3. Management of safety and care of the injured
Shahapur Taluka Bus Depot

- ~65 buses on 270 routes with a crew size of ~220 for 80 villages in Taluka
- The lowest load factor (.63) in Thane Division as per 2017 reports
Shahapur Taluka Bus Depot

- **Form 4**: Official schedule of buses prepared at Division Level with the help of Depot manager
- **Monthly Operational form or ABC**: Official document prepared at Depot level by the traffic controller with the help of ETIM* data and Data from Cashier’s office
- Grading paradigm followed A: Good, B: Needs Improvement, C: Poor

*ETIM: Electronic Ticket Issuing Machine*
Understanding Form 4

A form 4 is an official document that is essentially the bus schedule

Terminus: First or last bus stop of a bus service

Service: A bus service is a trip between terminals with *arrival time, departure time*

Schedule: A schedule is a set of services in such a way that the bus is not changed

Additionally **Crew duty** is a set of services such that the crew is not changed

An operational form 4 for any month is considered as **ABC form**
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शहीदपुर आगार
जेल्हापुक तक्ता क्र.: 4 सन्: 2017 - 2018
ABC TABLE

- An ABC table consists of the passenger load data, various earnings by any service of the schedule
- Every service is graded on EPKM (Effective Passenger Kilometres)
- If EPKM >= 43.32 Grade A
- If EPKM >= 22.1 && EPKM < 43.32 Grade B
- If EPKM < 22.1 Grade C
# ABC Operational Form

$$= (M12 \times 0.07053)$$

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Problems identified

- Lack of convergence of Transportation, GIS and Demographics data
- Drudgery in preparing ABC operational Data
- Lack of synchronisation between Form4, ABC and even ETIM data as well
- Lack of GIS data at Taluka Level
- Absence of unified database for Demand estimation and service provisioning
Research Question

Broad Societal Concern

“Poor Public transportation service provisioning in rural areas of Maharashtra”

DRQ. 1 What ICT tools can be developed for a rural public transportation system?

Research Objectives

• To define a model of Taluka public transportation based on graph theory
• To generate GIS data of transportation maps with points of importance, routes etc.
• To map Form 4 and Operational Data in GIS
• To integrate GIS, Operational and Census data together to generate analytics
Scope of the Project

- The field of study was in Shahapur Taluka, Thane District
- Only *lalpari* or Ordinary buses and bus-services are considered
- Data considered is based primarily on Form 4 data
- Non-MSRTC service providers data was collected through field surveys
- No Inter-city Bus services were considered
DIGITAL GEOGRAPHY
Graph theory

- A Graph $G$ is a data structure consisting of a set of Edges($E$) and Vertices($V$)
- Represented as $G(V,E)$
- Railway network, Stream network of watershed, Drinking water distribution lines etc.

$E = \{E_1, E_2, E_3, E_4, E_5, E_6\}$

$V = \{\text{सापगाव, डोलखांब, उम्बरखेड, किन्हवली, fata1, fata2}\}$
Graph Theory in Real life

Decision to choose path depends upon:

my requirement and who am I?

A Depot manager: routes with max coverage, shortest routes, routes with high profitability.

Tourist: monsoon season let’s explore scenic beauty on the way to डोलखांब
Bus networks as Graphs

- Derrible and Kenned (2010) to redraw metro networks into graphs $G(V, E)$ by removing the intermediate vertices and considering the end and transfer edges

$$V = V_t + V_e$$ where,$V_t$: Transfer station, $V_e$: End station

- $V_t$: Stations where it is possible to change routes without leaving the network
- $V_e$: Stations which form the beginning/end of a route segment
Digital Geography

- A digital geography is an undirected, planar graph $G(V, E)$
- where: $V$ is a set of vertices, $E$ is a set of edges
- Each member of $V$ and $E$ have geographical and geometrical properties
Definitions

- **Vertex (V):** A vertex is a point geometry that stores the lat-long coordinates. In our system, vertices are identified by $V = T \cup F$, where $V = T \cup F$.
  - **Terminal (T):** End stations
  - **Fata / Fork / Junction (F):** Transfer stations, Vertices with degree $> 2$

- **Edge (E):** A polyline between two vertices in such a way that there is no intermediate vertex.

- **Route Segment (RS):** Ordered set of Edges. $\{i, \} = \left\{E_{i1}, E_{i2}, E_{i3}, \ldots E_{in}\right\}$ where $n = \text{number of edges in } E$ and $\{E_{i1}, E_{i2}, E_{i3}, \ldots E_{in}\} \in E$.
So let's assume we have the following routes:

we have two route segments
from सापगाव to डडळखहामब and सापगाव to तकनहवलठ

then we have

\[ \pi_1: (E_1, E_4) \text{ and } \pi_2: (E_1, E_6) \]

\[ \pi_1 \cap \pi_2 = \{E_1\} \]

Overlapping vertices will be \{सापगाव, Fata 1\}
Implementation of Digital Geography by Google

Google Maps Platform

Family of APIs

Maps
- Javascript Maps
- Static Maps
- StreetView API

Routes
- Directions API
- Distance Matrix

Places
- Places API (points of interest)
- Geocoding
- Elevation API

IMPLEMENTATION OF DIGITAL GEOGRAPHY
Pre-Requisites

- Taluka Polygon File with Census data
- Form 4 and ABC form, Field data for determining the combinatorics of Termini
- Road network
- Google APIs to ascertain lat-long of termini
- Zila parishad schools data

Tool: QGIS 2.18 las palmas, pgAdmin4

DBMS: postgresql, PostGIS

Scripting: python 2.7

Packages: PyQt4

Data source: MRSAC, GISE lab IITB, Shahapur Taluka Bus Depot
SYSTEM ARCHITECTURE

Digital Geography

Graph Data Structure
- Vertices
  - Fatas
  - Terminals
- Edges

Operational Tier
- Form 4
- ABC Operational Data
- Non-MSRTC

Geographical Information System Tier
- Village
- Projections
- Census Data

Social Tier

Indicates Interaction

माझं गाव
माझं एस. टी.
A route segment is a polyline between any two distinct termini i.e. $RS \subseteq T^2$, Please note that we are not having any data of Edges till this step.
These polylines were generated using Google earth as we didn’t have MRSAC’s roads data of Nashik District and Mumbai Suburbs.
Terminals
Fatas / Forks / Junctions

- *Fatas* of ST bus road network and *fatas* of Road network
Set of fatas
- \( V = T \cup \mathcal{F} \)
- **Data cleaning:** postgres query to find the distance between two vertices, the vertices which were \(<250\) meters of distance were deleted
- Function used: `ST_DistanceSphere(geom1, geom2)`
Additional Definitions

- **Projections (P):** Point of shortest distance from village centroid
- **Hub distance:** Euclidian distance from village centroid to nearest route segment
Shapefile generated for Edges

Steps to find edges:

1. Find V intersection RS set
2. Order the vertices wrt their route segment
3. For every adjacent vertices in a route-segment find the shortest-path
Limitations of current methodology

- Roads were considered bidirectional and single lane
- The system works well with Single part geometries
- System doesn’t consider gradient in terrain (given Shahapur is a hilly area)
ADDING
OPERATIONAL
AND
CENSUS DATA
Data Cleanup and Migration done for ABC data and form4

- **Duplicacy** in bus service-ids
- Consistent names of Termini
- Arrival departure values which were previously not in timestamp data-type that was rectified
- Missing values of timings were extrapolated and fixed
- Migration of ABC table from excel format to postgresql
OUTPUTS
Coverage by Transportation
Manav Vikas Routes and count of bus services as per projections
Working Female population versus hub-distance in Shahapur Taluka

Total working females versus the hub distance

Number of Working females

35000
30000
25000
20000
15000
10000
5000
0

<1
between 1 and 2
greater than 2

Hub distance

32817
10386
7428
Field work at a glance

Duration and frequency
- 8 (1 day per visit) Visits to Shahapur Taluka depot
- One particular 3-day stay in Taluka to understand the daily schedule of traffic dept., depot manager
- 6 (1 day per visit) Visits to MSRTC Mumbai Central Office
- 2 (1 day per visit) Visits to Thane Division Office Traffic department

Agenda
- To understand the working of a bus-depot
- To collect relevant data and formats
- To understand the daily schedule/job roles in a depot
- To interview and survey non-MSRTC service providers
Conclusion

- Identification of ICT as a key ingredient in bus service provisioning
- Our system tries propose a methodology for converting given road network of MRSAC into Digital Geography
- This data should be given by default by MRSAC to MSRTC
- Digital Geography will help in strengthening our Taluka depots with better decision support systems so that Regional Transportation Development plan can be developed
Future scope

- Analysis of Punctuality data with profitability
- Rescheduling the bus services on the basis of network model
- Deeper analysis of multi-modal transportation in Shahapur Taluka
- Testing the methodology in 3 talukas with different geographies and demographics
- Inter-city transportation analysis for tackling bus-bunching problem
- Identification of routes with maximum coverage, minimum distance and high profitability
Thank you!
Schematic for the RS generation

Here,
**t1_t2_rs**: Table consisting of combinations of termini

**Termini table**: Table consisting of geometries corresponding to termini

**Query1**: Inner join query that joins the two tables above

**P1**: python script that takes in the combinations of termini along with their lat-long; generates the shortest-path between them based on MRSAC data; generates the route-segment id and updates the geometry to RS shapefile

**Query2**: Update query to update RS_id in t1_t2_rs

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Schematic V intersects RS

- Route-Segment Shapefile
  - v.buffer/
    Fixed Distance Buffer
- Vertex Shapefile
- Buffered Route-Segment Shapefile
  - Intersection
  - $RS_i \cap V$
Schematic for Edge creation

**P2:** fetches the geometries from the three shapefiles, creates **Edge Shapefile**, updates **v1_v2_e** with **Query 3**, updates **rs_e** with the ordered set of edges for each RS

**v1_v2_e:** table that stores the combinatorics of vertices wrt edges

**rs_e:** table that stores the ordered set of edges for each RS

**Query3:** Insert query to populate **v1_v2_e**

**Query4:** Insert query to populate **rs_e**
DATABASE DESIGN 1.2

Diagram showing relationships between entities such as Edge, Vertex, Route-Segment, Projections, Village, Bus-Service, Schedule, Terminal, and Fata.
Villages highlighted in Red represents no direct access to roads.
Overall Transportation Coverage

Legend:
- Light Blue: ST bus network
- Red: Jeep network
- Dark Blue: Minidor network
- Yellow: Shared Auto-rickshaw network
Operational Data of Form 4

Legend

cat_bus_services_form4 [372]
- A [16]
- B [3]
- C [212]
- D [141]
- All Vertices [396]
- Route-segments of Form 4 [699]
- coverage_as_per_form4
- Termini [86]
- All Route-segments [166]
- shahapur_taluka_boundary_validated [223]

Red lines represent that the region is not covered by bus as per form 4.
Manav-Vikas routes and %SC-ST Population
Population Density

Legend

Shahapur Population Density (equal quantile count) [222]

- 1.9200 - 131.8300 [74]
- 131.8300 - 219.6600 [74]
- 219.6600 - 11312.3200 [74]
Count of bus services as per form 4
Overlapping Freq data over %SC-ST population
Over Manav-vikas routes
Basic Crew Duty analysis of Form 4

Total Schedules : 56
Total Crew Duties : 108
Total Duty Hours : 874 hours 25 mins
Total Occupied Hours : 637 hours
Coverage as per form 4 and projections