Interdisciplinarity and Engineering

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IIT Bombay (and IIT Goa)

Dedicated to the memory of Prof. D.M. Dhamdhere

My first teacher of Computer Science.

Interdisciplinarity and Engineering

Where will jobs come from
How will the new society work

Public Transport as an Example

(Work of Sudhanshu, Anshu, Sunny, Anshul, Ramya and Jitu Sir)

What will we cover

What is engineering.

- How do we measure it.
- How are we doing.
  Engineering Systems - Embedded in society.

Public Transport - A Case Study

- Importance of public transport.
  Measuring public transport.
- A Taluka Bus Depot.
- Form IV and what it allows us
- Ticketing and what that gives us
- GIS and its uses
- Optimization models

Conclusions

Engineering Questions

Industrial

- Make food products and ganapatis, mosquito swatters, masks, ventilators
- Capacity to manufacture fighter-planes, or CNC machines, refine petroleum, create databases, polish rice

Social Metrics - Consumption Side

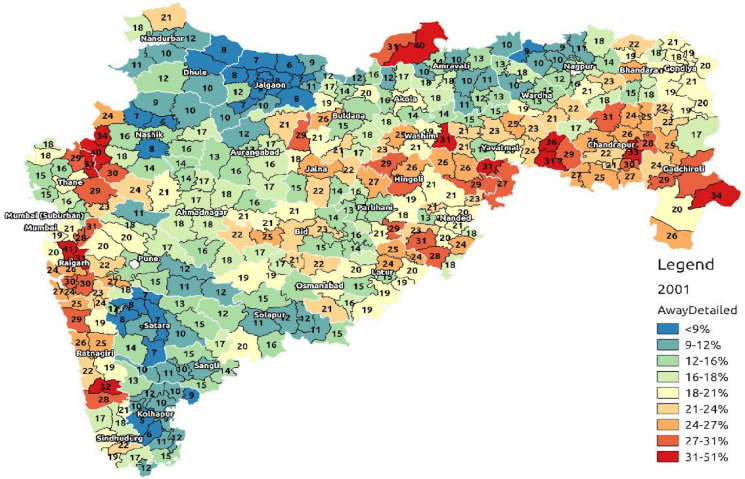
- Number of microscopes per 1 million
- Number of Buses per 1 million
- %-age farmers with access to electricity
- %-age with tap water at home

Other social metrics

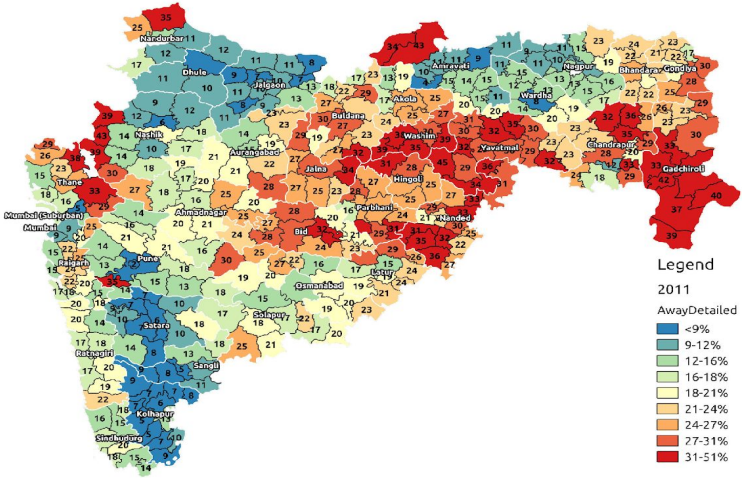
- Number of books published per 1 million
- Number of different birds seen within a district
- How much time is there free flow in the river after monsoons?
- Number of inter-caste marriages

Development Deficit

Percentage of Rural Households with Primary Source more than 500m away (2001)



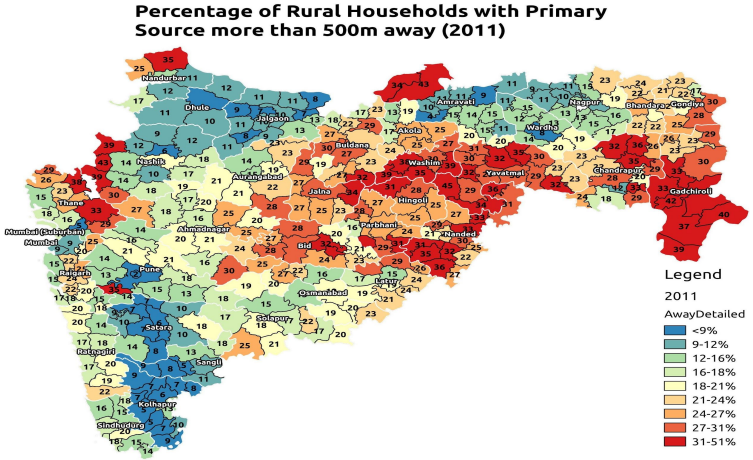
Percentage of Rural Households with Primary Source more than 500m away (2011)

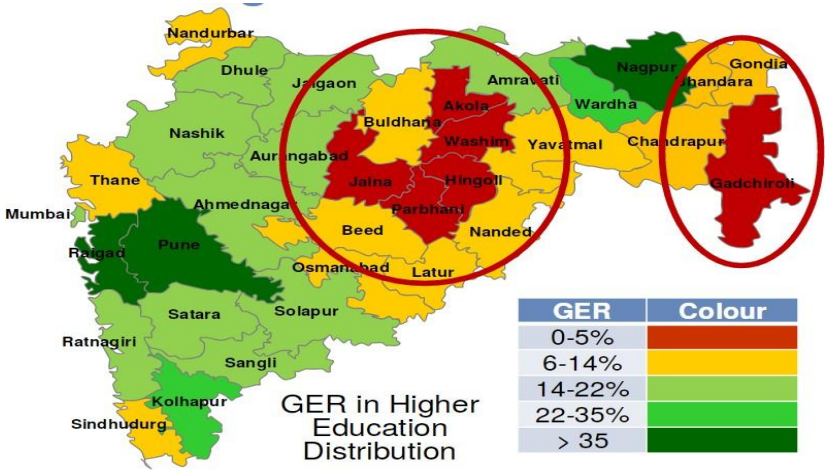


Drinking water: *Its getting farther and farther. Its also not available year-round.* **The same with cooking energy.**

Data Source: Census Data.

And its consequences - In education





Should this surprise us?

Fetching water and firewood occupies 2-3 hours. Going to place of work, school, college. Work of great drudgery and poor working conditions.

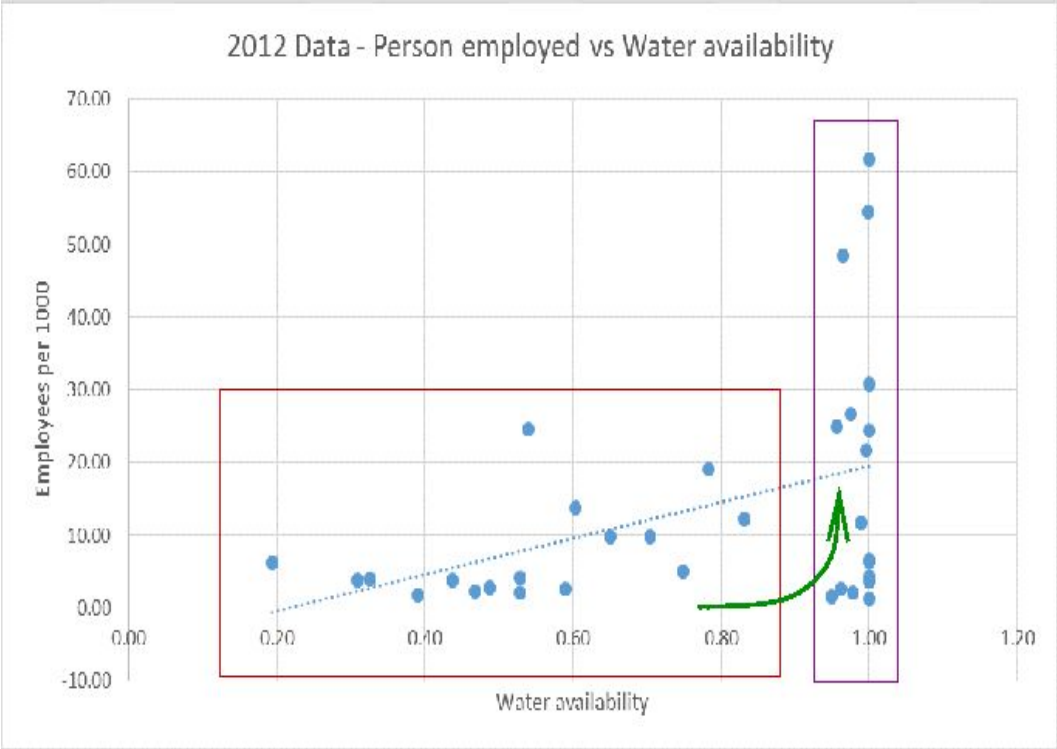
Another Connection

District-wise Urban Water Availability and Jobs

Better Amenities ⇒ More jobs.

We need Industrial Revolution 2.0!

So Why are we doing so badly?



Why are we like this? - *The first clue!*

Per capita Steel consumption in kgs/year

India	57	China	477
Other Asia	69	Japan	506
Egypt	95	USA	306
UK	145	Netherlands	200

There is no demand! We are unable to find business models or social/financial models to bring about desirable change!

Why?

- **It needs better analysis and research - better training**
- **It needs formal entry points. - better employment opportunities**

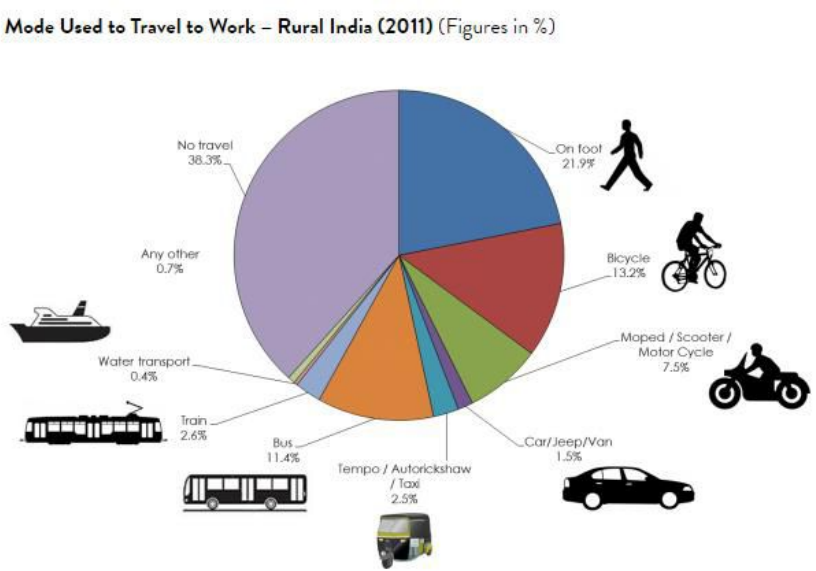
Why are we like this? Better Analysis!

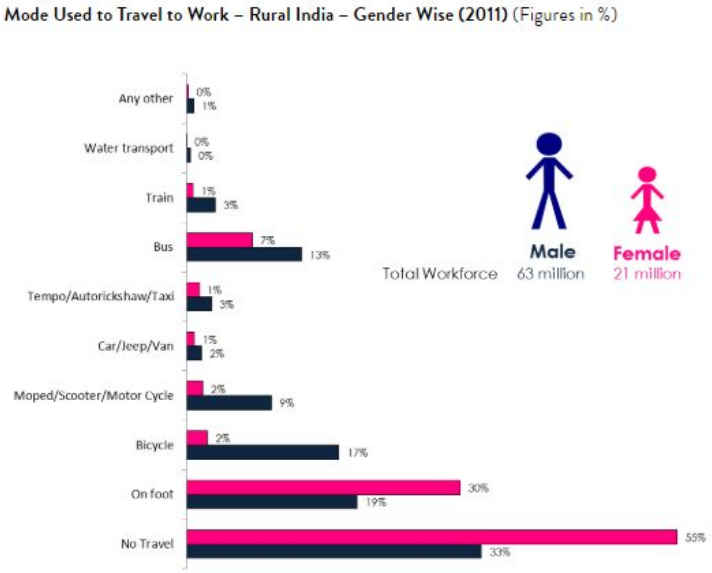
Lets take up a sector and understand these problems better! **Public Transport**

- **Its a ZOO out there - Systems**
- **Many animals - Models**

1. Importance of the sector and the Taluka Bus Depot
2. Time-Table and Form IV, GIS
3. Ticketing and Ridership
4. Access

What does the census say on transport





https://india.uitp.org/articles/mobility-in-rural-india

MSRTC

Staff Strength	1.05 lakhs
Number of Buses	15500
Staff per Bus	5.79
KM per Bus per Day	310 km
KM per Staff Per Day	54 km
Fuel Efficiency	4.76 km/liter

Repeated Losses

Rising fuel costs compels corporation to increasing MSRTC bus fares by 18%

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 transport utilities in India having fleet of 18,000 active buses and 60 lakh daily passengers. But it has been suffering from financial losses due to expenditure on salaries, fuel and passenger tax charged by the state government.

hindustantimes

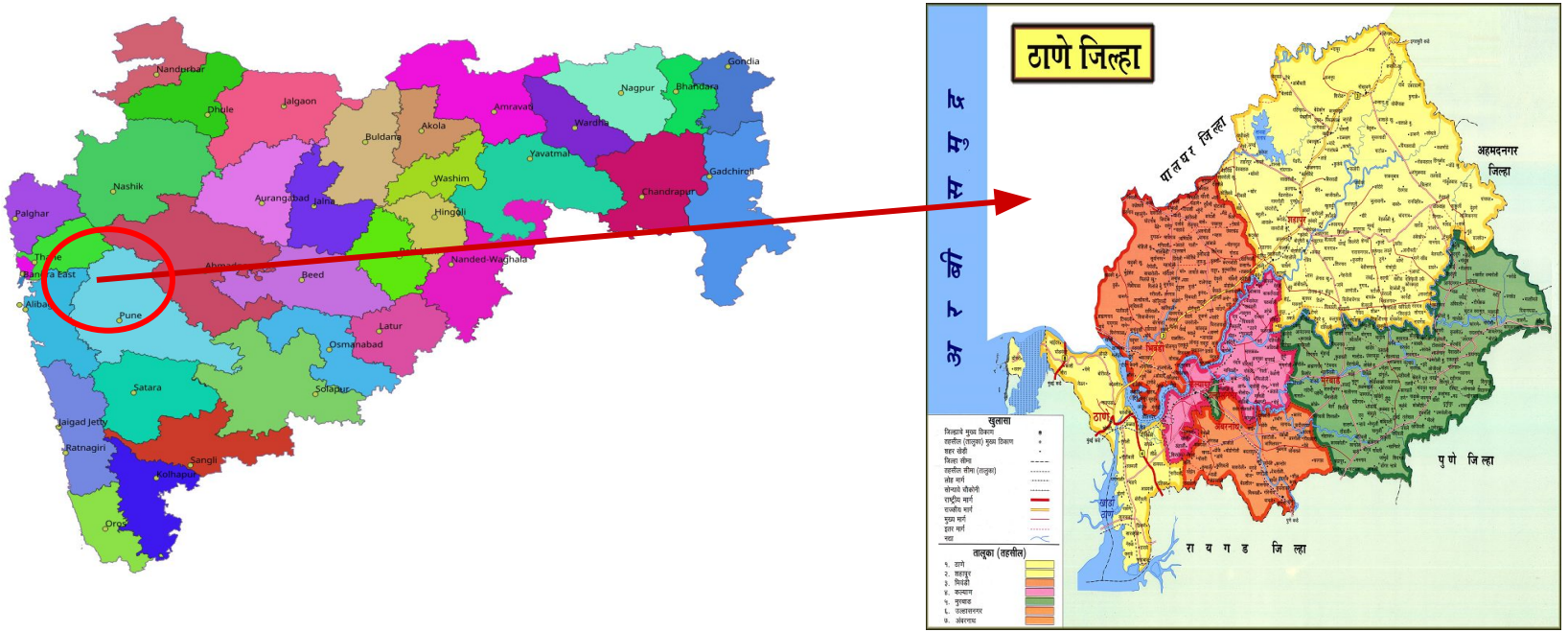
PUC panel reports points out MSRTC's losses, blames e-ticketing system

Waive taxes for MSRTC, Transport Minister urges CM

अ.क्र./ Sr. No.	तपशील / Particulars	वाहतूक सेवा उपलब्ध असलेल्या खेडयांची टक्केवारी/ Percentage of Villlages served		वाहतूक सेवा उपलब्ध असलेल्या लोकसंख्येची टक्केवारी / Percentage of Population served	
		2015-16	2016-17	2015-16	2016-17
1	2	3	4	5	6
अ/ A	थेट / Direct	74.48 (30906)	75.53 (31341)	91.17 (1099.66)	91.66 (1119.86)
ब /B	३ कि.मी.पर्यंत/ Upto 3 Kms.	15.72 (6524)	15.11 (6269)	5.85 (70.52)	5.61 (68.49)
क /C	३ ते ५ कि.मी. दरम्यान/ Between 3 to 5 Kms.	5.61 (2328)	5.42 (2247)	1.68 (20.27)	1.59 (19.44)
ड /D	५ ते ८ कि.मी.दरम्यान/ Between 5 to 8 Kms.	2.57 (1067)	2.44 (1014)	0.86 (10.33)	0.74 (8.98)
इ /E	८ कि.मी.पलिकडे / Beyond 8 Kms.	1.61 (668)	1.50 (622)	0.45 (5.38)	0.40 (4.92)

corporation.

Let’s zoom in…



Shahapur taluka, Thane district: about 3.6 lakhs (2011), partly urban, 1616 sq. km.

Shahapur Bus Depot

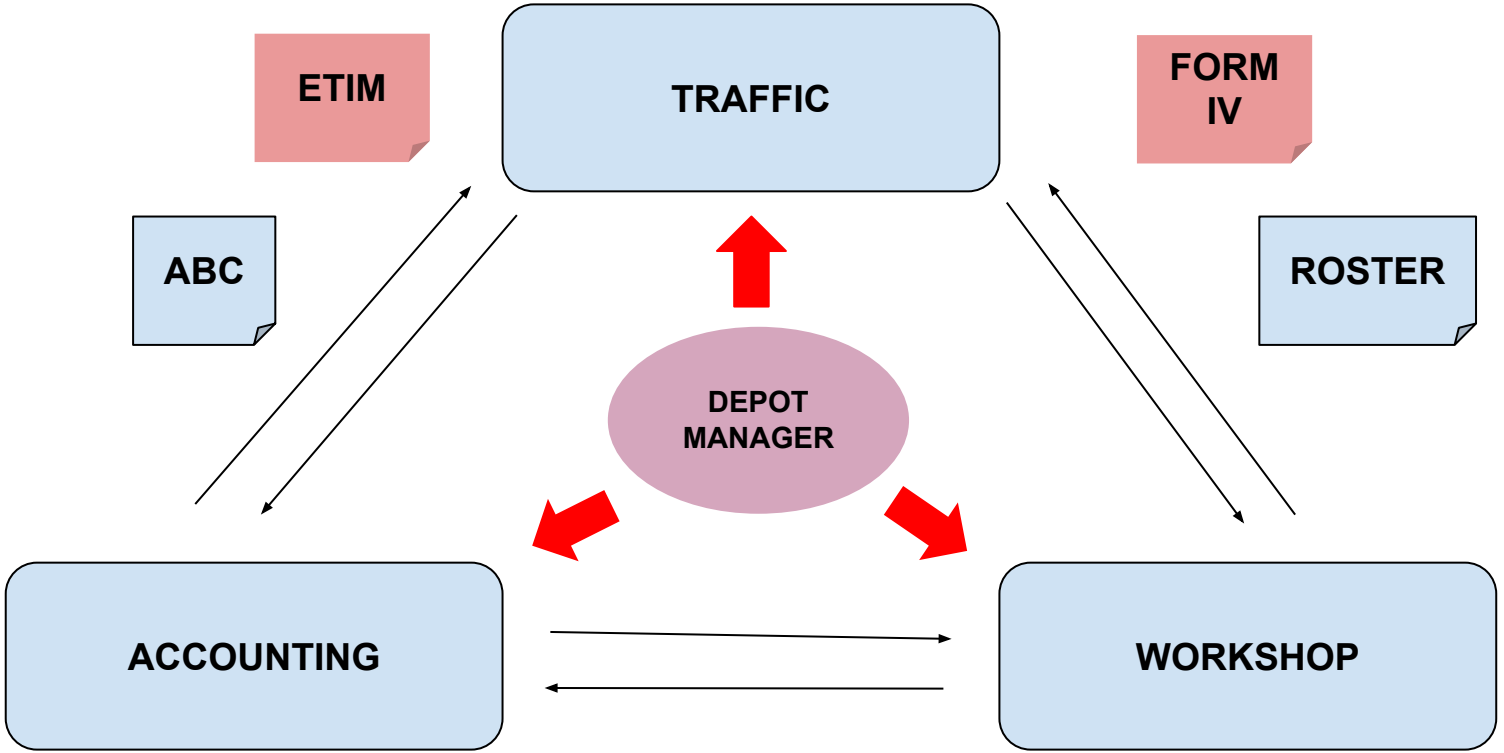
Key Data: 65 Buses, ~220 staff, 270 Routes, 80 villages, load factor 63%.

More data

Category	EPKM Range	Number of Routes
A	>Rs 43	15 %
B	Rs 22-43	40 %
C	<Rs. 22	45 %

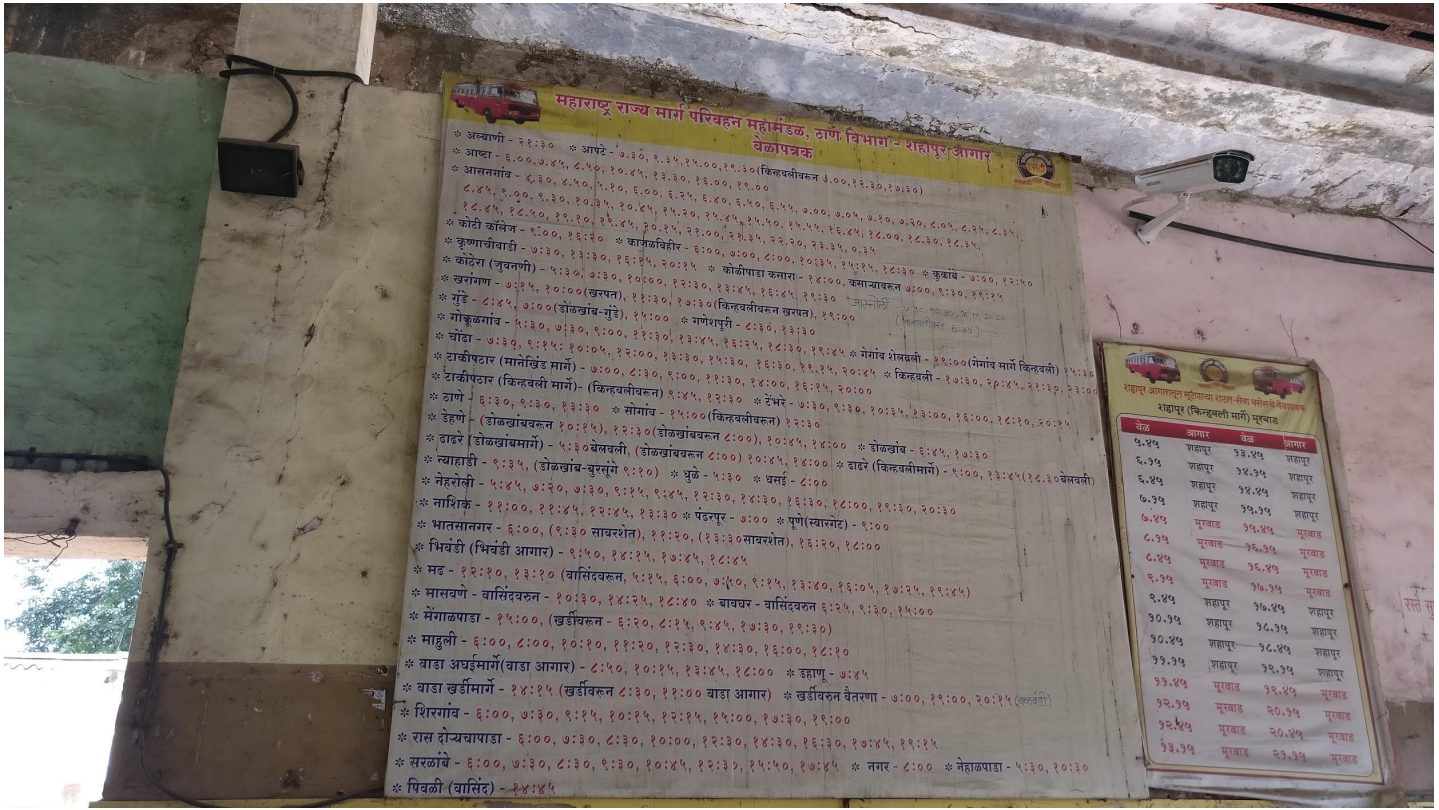
Key Research Question: How to make Shahapur Taluka Bus Depot profitable - financially or socially.

And Computer Scientists can do a lot - Systems approach!


ETIM
TRAFFIC
FORM IV
ABC
ROSTER
DEPOT MANAGER
ACCOUNTING
WORKSHOP

Designation	Task	Input	Output	Used By	Stored at	Stored as
Announcer	Announces the arrival of the buses	**Bus schedule from MSRTC Portal**	Announcement	Announcer	MSRTC Server	Softcopy
				Passenger	NA	NA
	Updates the Control chart with arrival time of the bus	**Control Chart**	Arrival timing of Bus	Depot Manager	T29 Office	Hardcopy
Traffic Controller	Assigning duties to the crew as per daily shift schedule	**Daily Attendance of the crew**	Daily shift allocation schedule	Traffic Controller	Traffic Controller Office	Hardcopy
		Shift schedule roster		Depot Manager		
	Revenue Report	**Hard-copy of ETIM Daily Revenue data from TRIMAX**	Updated Current Month's updated table with ABC grading of the Bus Services	Traffic Controller	Traffic Control Office	Softcopy
		Last month's ABC table		Divisional Traffic Controller	Thane Division Office	
T29 clerk	Maintaining Files (Control Chart)	**Last month's ABC table**	Updates daily control chart	Announcer	T29 Office	Hardcopy
TRIMAX Staff	Printing reports, technical support of ETIM portal	**Credentials**	Hard-copy of ETIM daily revenue report	Traffic Controller	Traffic controller office	Hardcopy

The Timetable



The Form IV

शहापुर आगार

वेळापत्रक तक्ता क्र.4 सन :-2017 - 2018

नियत		कामगिरी	फेरीचा			वेळ				शेरा	थांबे
क्र.		क्र.	सांकेतिक क्र.			अंतर	सुटते	पोहचते			
			अटल सेवा								
1	0	C-1	S-81482	SHAHAPUR	MURBAD	42.7	5.45	7.15	KINHAVALI	विश्रांती	
1		C-1	S-81483	MURBAD	SHAHAPUR	42.7	7.45	9.15	KINHAVALI	मार्ग:- किन्हवली.	
1		C-1	S-81484	SHAHAPUR	MURBAD	42.7	9.45	11.15	KINHAVALI	मार्ग:- किन्हवली.	
1	0	C-1	S-81485	MURBAD	SHAHAPUR	42.7	11.45	13.15	KINHAVALI	मार्ग:- किन्हवली.	
1	0			चा/वा बदल							
1	0	C-2	S-81486	SHAHAPUR	MURBAD	42.7	13.45	15.15	KINHAVALI	मार्ग:- किन्हवली.	
1		C-2	S-81487	MURBAD	SHAHAPUR	42.7	15.45	17.15	KINHAVALI	विश्रांती	
1		C-2	S-81488	SHAHAPUR	MURBAD	42.7	17.45	19.15	KINHAVALI	मार्ग:- किन्हवली.	
1	0	C-2	S-81489	MURBAD	SHAHAPUR	42.7	19.45	21.15	KINHAVALI	मार्ग:- किन्हवली.	
	0					वाहन देखभाल वेळ21.15 ते 5.45 .					

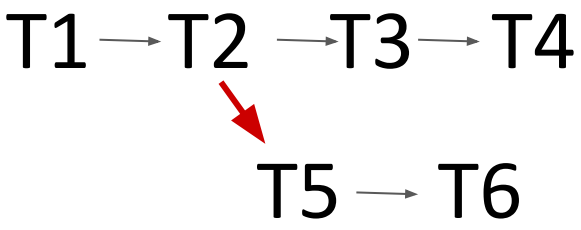
Trip = (source, destination, distance, start-time, end-time)

Schedule =(T1,T2,...,Tk) - same crew, same vehicle, 8hrs **Form IV = S1,S2,,...,Sk**

Important Problem

How many buses are needed to serve a time-table?

How can these be clubbed into schedules?

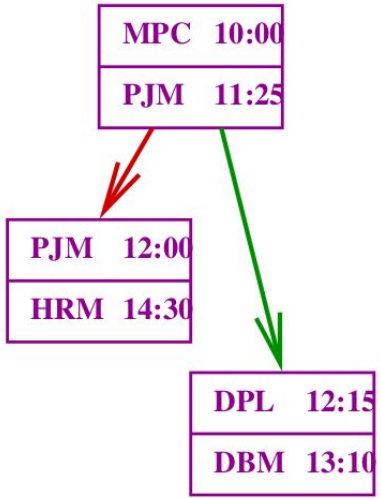


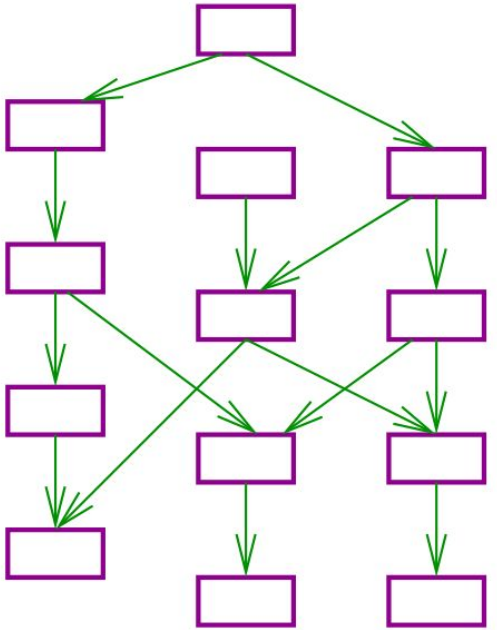
- **Affects both Quality of Service as well as efficiency**
- **How much is the gap between trips? Can that be reduced?**
- **Can trip-links be done dynamically in case of delay?**

The Whole TT

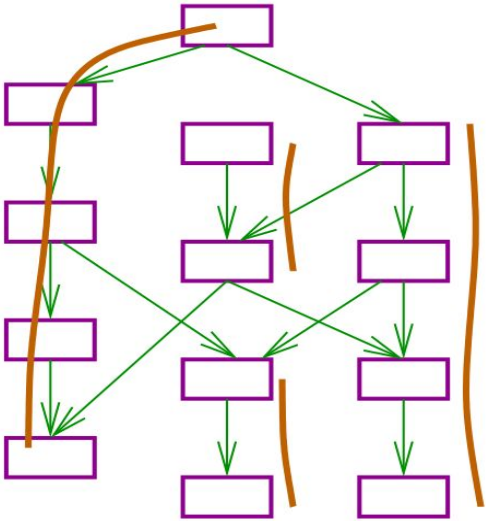
- Look at it one service at a time.
- List all services which can follow it for a bus
  - Time gap allowed.
  - Empty travel.
- Do it for all the services

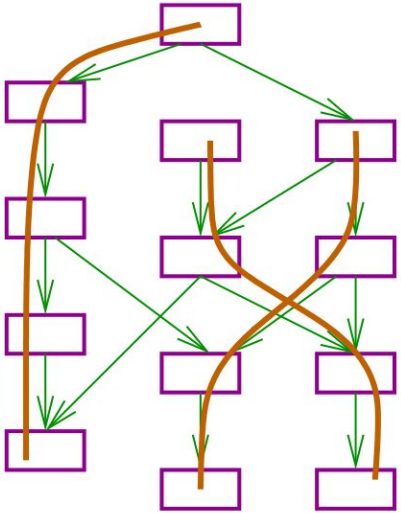
The Master POSET





The Min-Cost Flow Problem



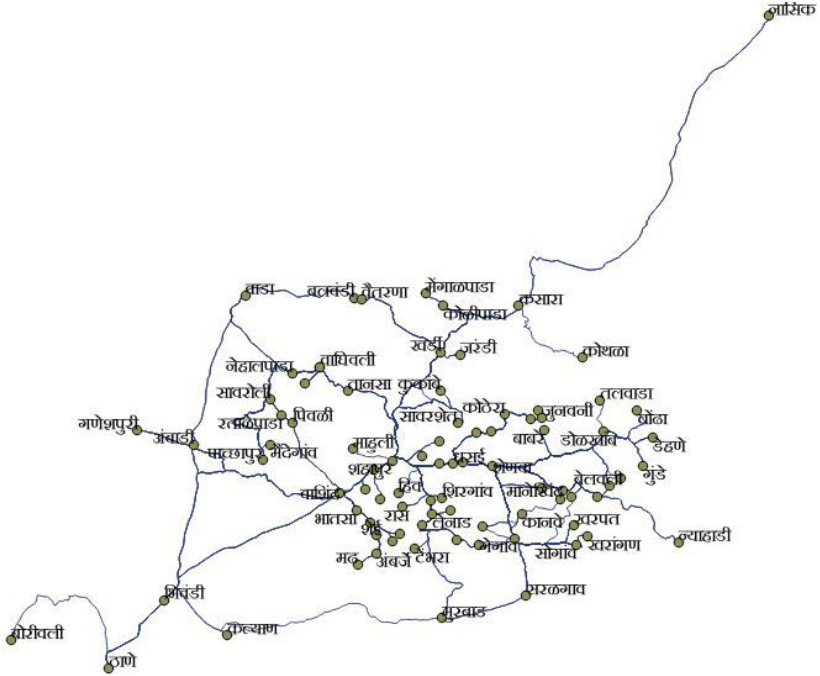


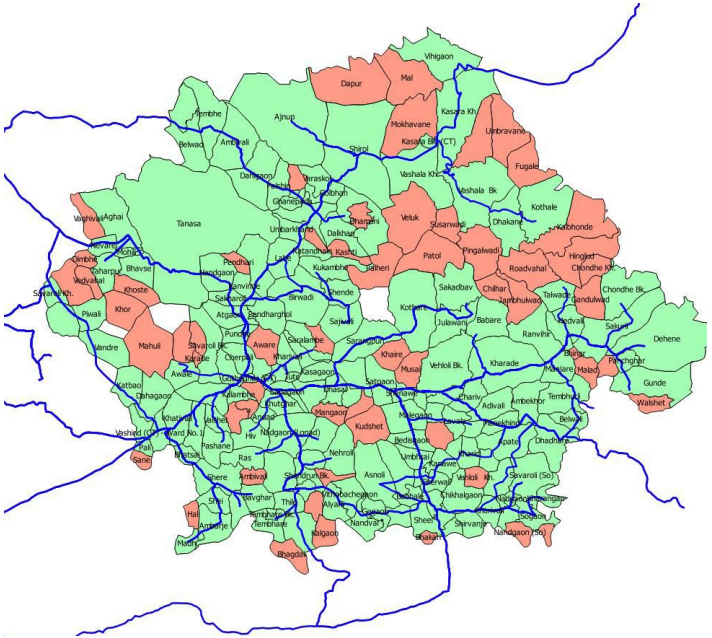
Path Coverings of Trips - Number of Buses!

But this representation has problems...

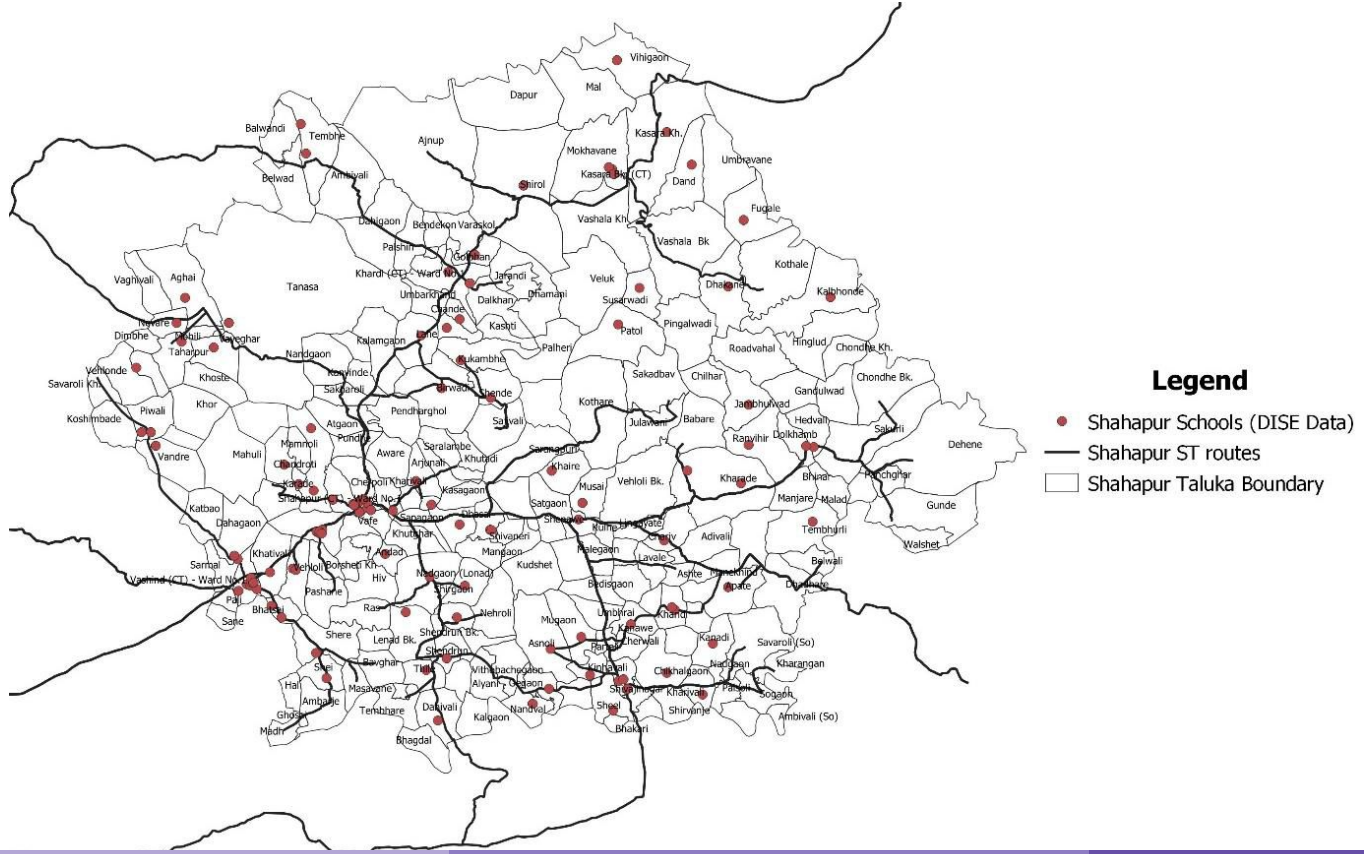
1. What are the villages/stops on a particular trip?
   ETIM (the ticketing data)
2. How many villages are covered? How many schools are covered?
3. How many trips pass through a given location? Do dense areas have more trips?

Just use Maps and **GIS**... *and the Shahapur village data-set*



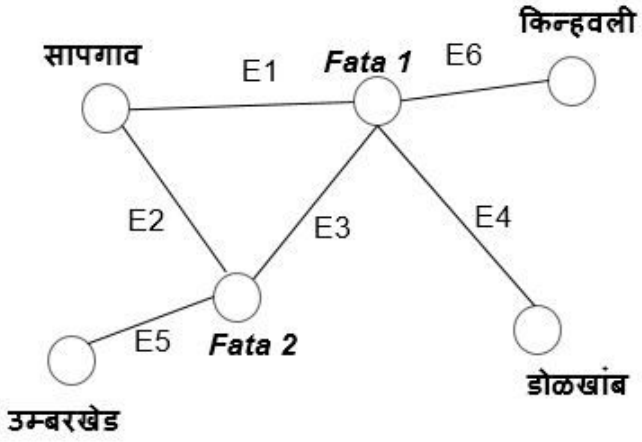


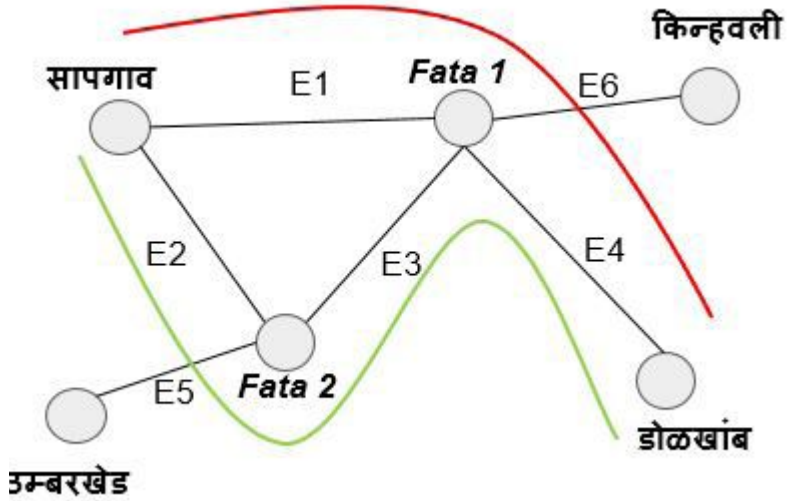
Shahapur taluka - ST network and schools



How many trips pass through a given location? Do dense areas have more trips?

Requires connecting geography and schedule!

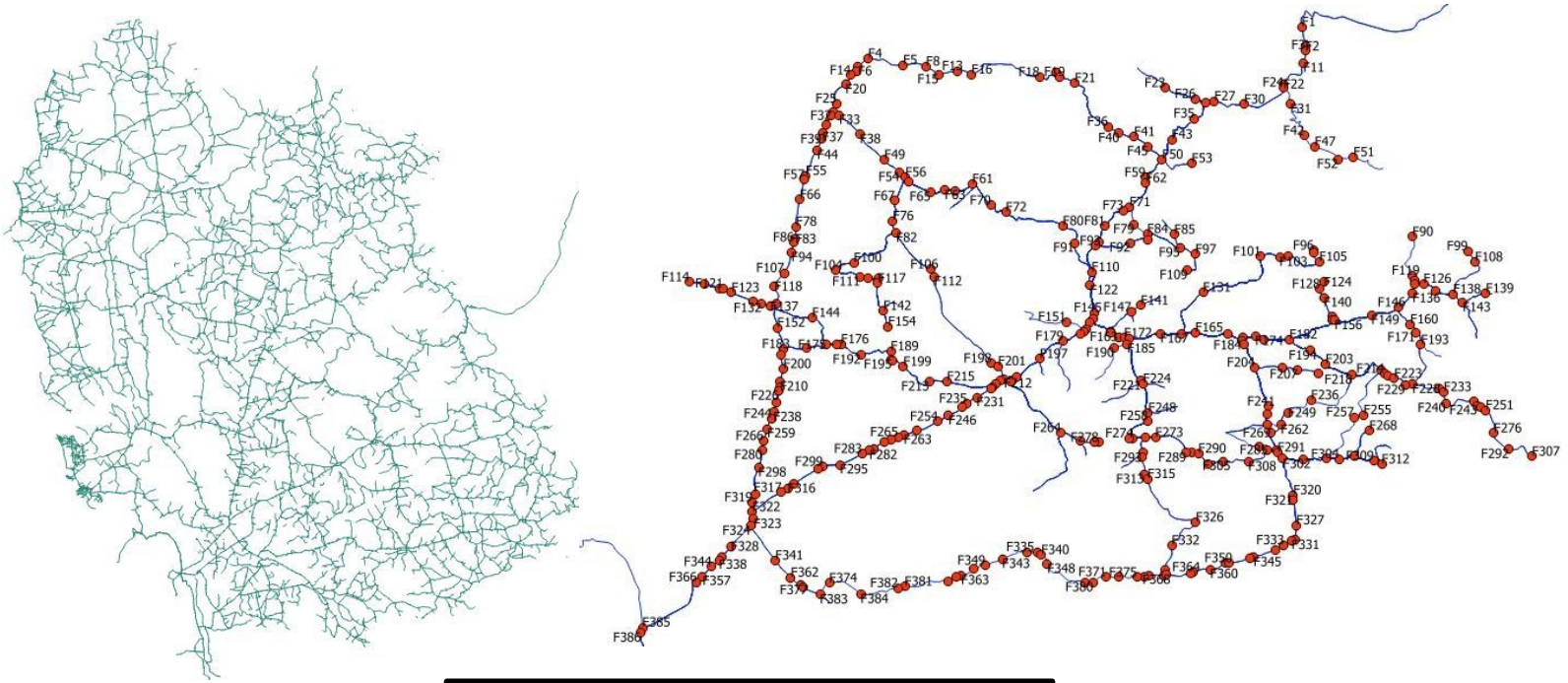




E = *{E1, E2, E3, E4, E5, E6}*
V = *{* सापगाव, डोळखांब, उम्बरखेड, किन्हवली, *fata1,fata2}*

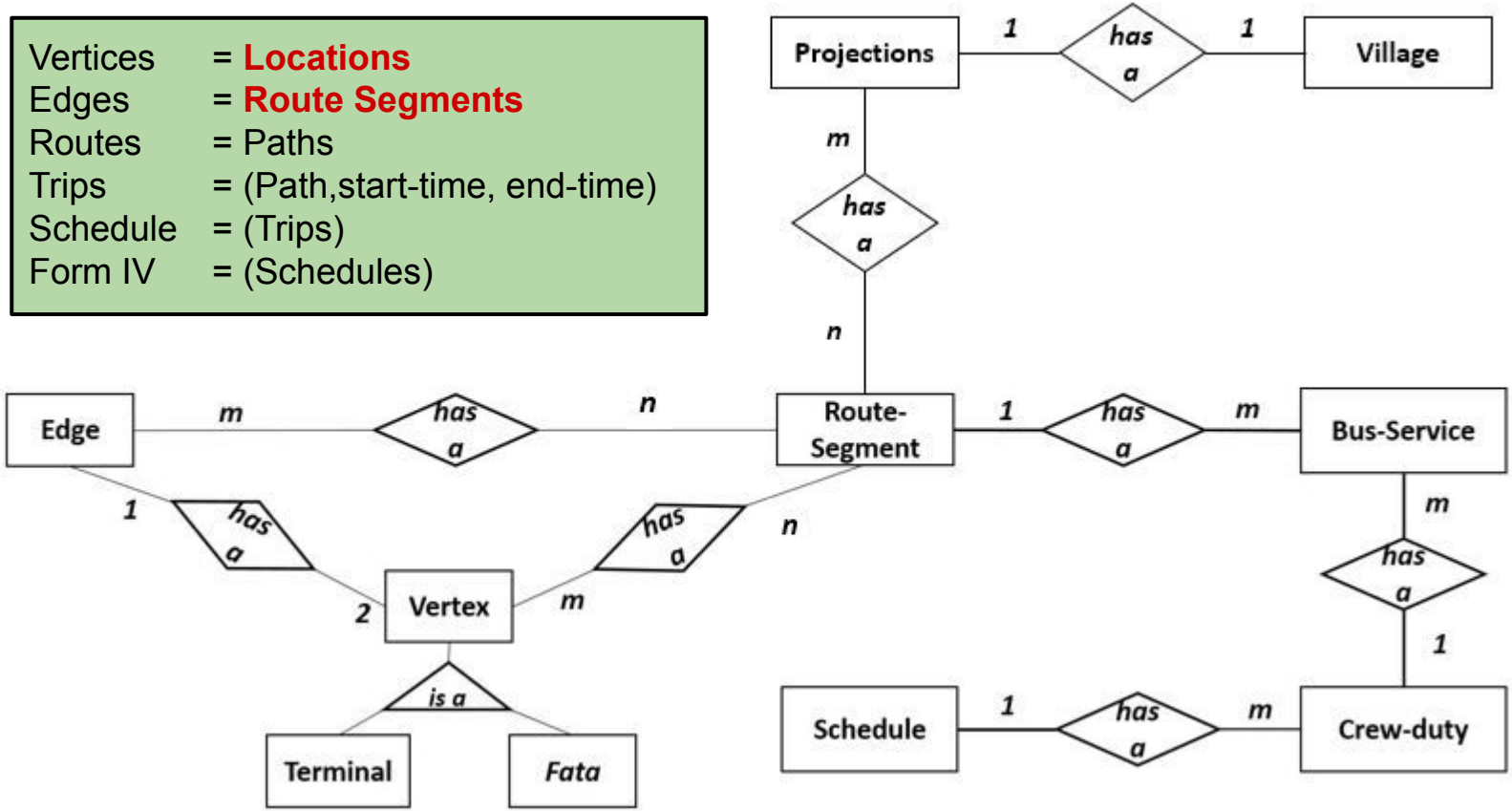
We use a Graph Structure. Digital Geography!

(Destination-Pairs)+Road-Network=Vertices+Edges

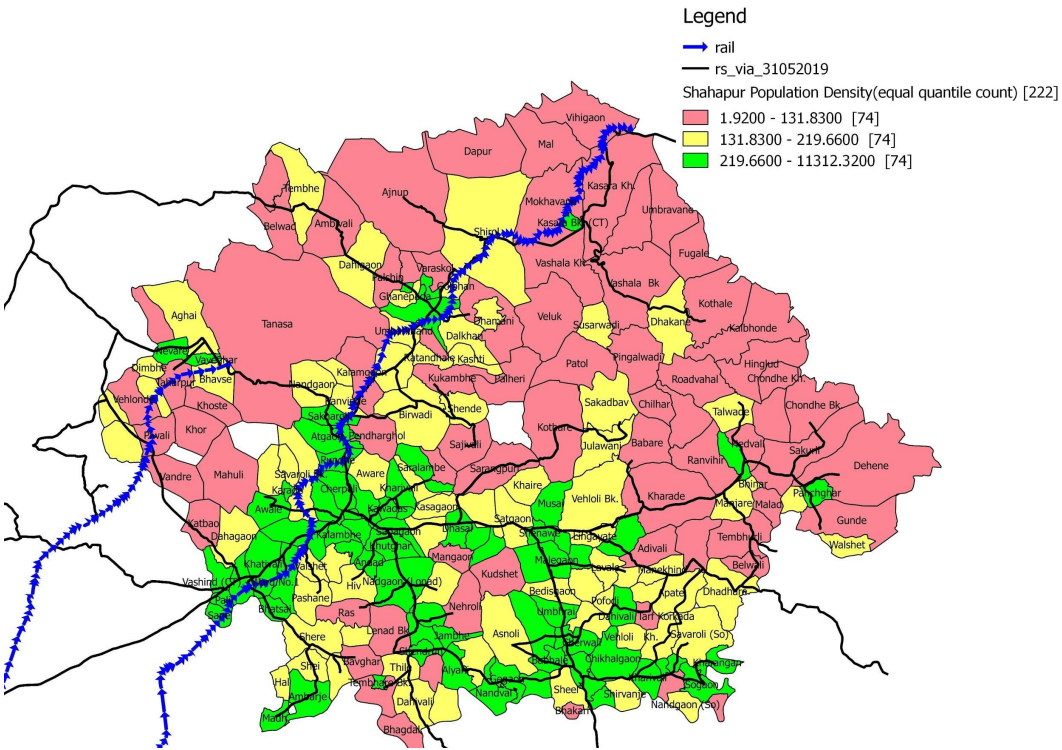


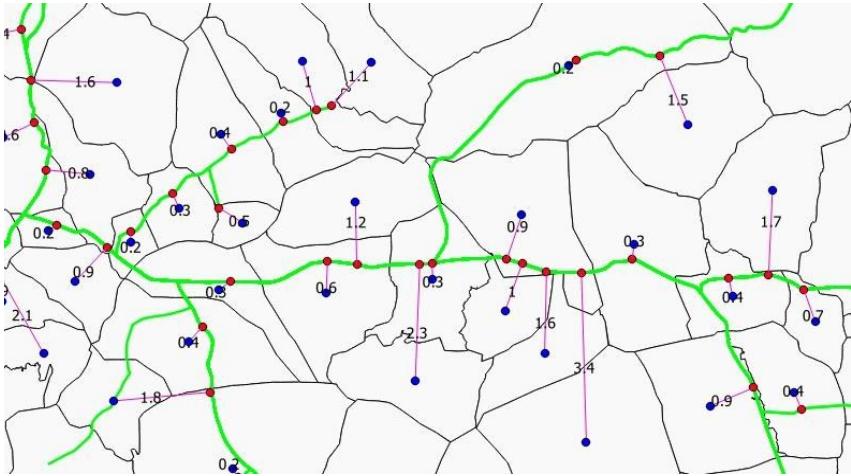
Huge Reduction in Data!

Vertices	= **Locations**
Edges	= **Route Segments**
Routes	= Paths
Trips	= (Path,start-time, end-time)
Schedule	= (Trips)
Form IV	= (Schedules)



Coverage and Access





Key Problem: Timetables

Form IV has only end-to-end times. No intermediate times!

Task: Construct time-table for intermediate stops.

- Route = Path in graph.
- Edges = route-segments - attributes such as length, road-type.
- Start-time and End-time.

Interesting Data-fitting Problem.

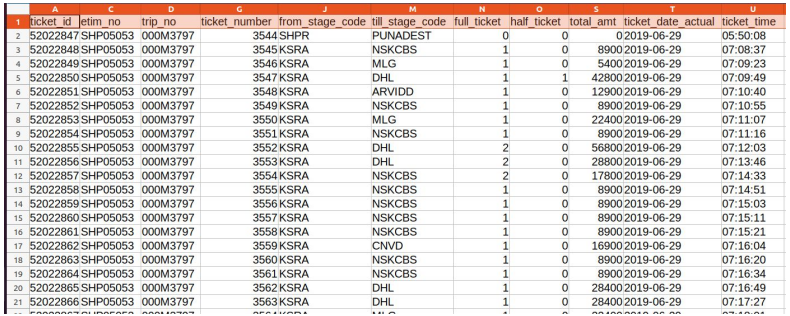
Check with local riders, conductors and traffic manager.
Ride the buses! Crowd-source. (IIT Dharwad) - Stop names and times

The ETIM Machines

Ticketing Data

	A	C	D	G	J	M	N	O	S	T	U
1	ticket_id	etim_no	trip_no	ticket_number	from_stage_code	till_stage_code	full_ticket	half_ticket	total_amt	ticket_date_actual	ticket_time
2	52022847	SHP05053	000M3797	3544	SHPR	PUNADEST	0	0	0	2019-06-29	05:50:08
3	52022848	SHP05053	000M3797	3545	KSRA	NSKCBS	1	0	8900	2019-06-29	07:08:37
4	52022849	SHP05053	000M3797	3546	KSRA	MLG	1	0	5400	2019-06-29	07:09:23
5	52022850	SHP05053	000M3797	3547	KSRA	DHL	1	1	42800	2019-06-29	07:09:49
6	52022851	SHP05053	000M3797	3548	KSRA	ARVIDD	1	0	12900	2019-06-29	07:10:40
7	52022852	SHP05053	000M3797	3549	KSRA	NSKCBS	1	0	8900	2019-06-29	07:10:55
8	52022853	SHP05053	000M3797	3550	KSRA	MLG	1	0	22400	2019-06-29	07:11:07
9	52022854	SHP05053	000M3797	3551	KSRA	NSKCBS	1	0	8900	2019-06-29	07:11:16
10	52022855	SHP05053	000M3797	3552	KSRA	DHL	2	0	56800	2019-06-29	07:12:03
11	52022856	SHP05053	000M3797	3553	KSRA	DHL	2	0	28800	2019-06-29	07:13:46
12	52022857	SHP05053	000M3797	3554	KSRA	NSKCBS	2	0	17800	2019-06-29	07:14:33
13	52022858	SHP05053	000M3797	3555	KSRA	NSKCBS	1	0	8900	2019-06-29	07:14:51
14	52022859	SHP05053	000M3797	3556	KSRA	NSKCBS	1	0	8900	2019-06-29	07:15:03
15	52022860	SHP05053	000M3797	3557	KSRA	NSKCBS	1	0	8900	2019-06-29	07:15:11
16	52022861	SHP05053	000M3797	3558	KSRA	NSKCBS	1	0	8900	2019-06-29	07:15:21
17	52022862	SHP05053	000M3797	3559	KSRA	CNVD	1	0	16900	2019-06-29	07:16:04
18	52022863	SHP05053	000M3797	3560	KSRA	NSKCBS	1	0	8900	2019-06-29	07:16:20
19	52022864	SHP05053	000M3797	3561	KSRA	NSKCBS	1	0	8900	2019-06-29	07:16:34
20	52022865	SHP05053	000M3797	3562	KSRA	DHL	1	0	28400	2019-06-29	07:16:49
21	52022866	SHP05053	000M3797	3563	KSRA	DHL	1	0	28400	2019-06-29	07:17:27

What's in it?



	A	C	D	G	J	M	N	O	S	T	U
1	ticket_id	etim_no	trip_no	ticket_number	from_stage_code	till_stage_code	full_ticket	half_ticket	total_amt	ticket_date_actual	ticket_time
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12	52022857	SHP05053	000M3797	3554	KSRA	NSKCBS	2	0	17800	2019-06-29	07:14:33
13	52022858	SHP05053	000M3797	3555	KSRA	NSKCBS	1	0	8900	2019-06-29	07:14:51
14	52022859	SHP05053	000M3797	3556	KSRA	NSKCBS	1	0	8900	2019-06-29	07:15:03
15	52022860	SHP05053	000M3797	3557	KSRA	NSKCBS	1	0	8900	2019-06-29	07:15:11
16	52022861	SHP05053	000M3797	3558	KSRA	NSKCBS	1	0	8900	2019-06-29	07:15:21
17	52022862	SHP05053	000M3797	3559	KSRA	CNVD	1	0	16900	2019-06-29	07:16:04
18	52022863	SHP05053	000M3797	3560	KSRA	NSKCBS	1	0	8900	2019-06-29	07:16:20
19	52022864	SHP05053	000M3797	3561	KSRA	NSKCBS	1	0	8900	2019-06-29	07:16:34
20	52022865	SHP05053	000M3797	3562	KSRA	DHL	1	0	28400	2019-06-29	07:16:49
21	52022866	SHP05053	000M3797	3563	KSRA	DHL	1	0	28400	2019-06-29	07:17:27

(trip_ID, date, start_dest.,end_dest.,time_of_issue,fare)

Many troublesome issues:

- **When did the trip start?**
- Are the destination IDs standard?
- Are the trip IDs standard?

Punctuality

	A	B	C
	trip_status	no_of_etim_july_trip	percentage
	as scheduled(10-20mins)	**2767**	**23.04**
	as scheduled(within 10mins)	**5359**	**44.63**
	cannot say late/early(9-12hrs)	63	0.52
	cannot say late/early(more than 12hrs	25	0.2
	early	**830**	**6.91**
	early by 1-2hrs	118	0.98
	early by 2-4hrs	58	0.48
	early by 5-8hrs	125	1.04
0	**late**	**2254**	**18.77**
1	late by 1-2hrs	306	2.54
2	late by 2-4hrs	81	0.67
3	late by 5-8hrs	21	0.17
4	**total**	**12007**	
5			

- **No record when the trip started or ended.**
- Based on ETIM time-stamps.
- Analysis for starting stops!

GPS Based Time-Stamping Essential. Guidance to passengers too!

Profitability

Trip Earnings = Monthly total of daily earnings
Distance Traveled = 30*trip length
EPKM=TripEarnings/Distance

More to this: Baggage, Pass-holders, Free-passes.

But there is no other social accounting or disaggregation.

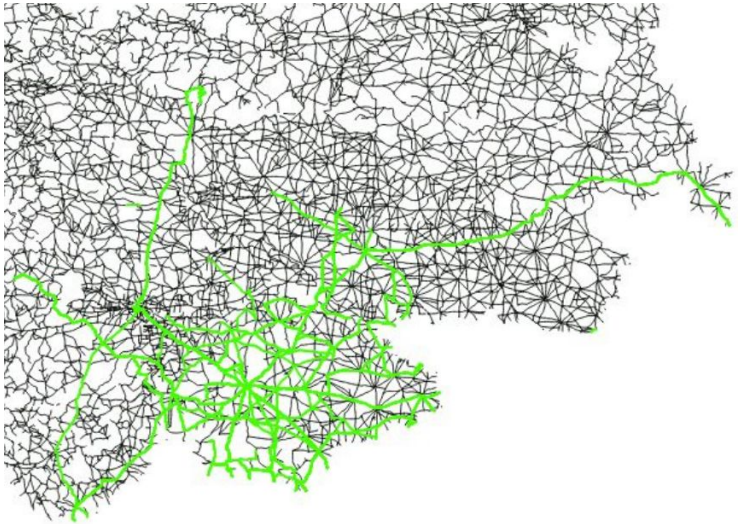
That would have helped!

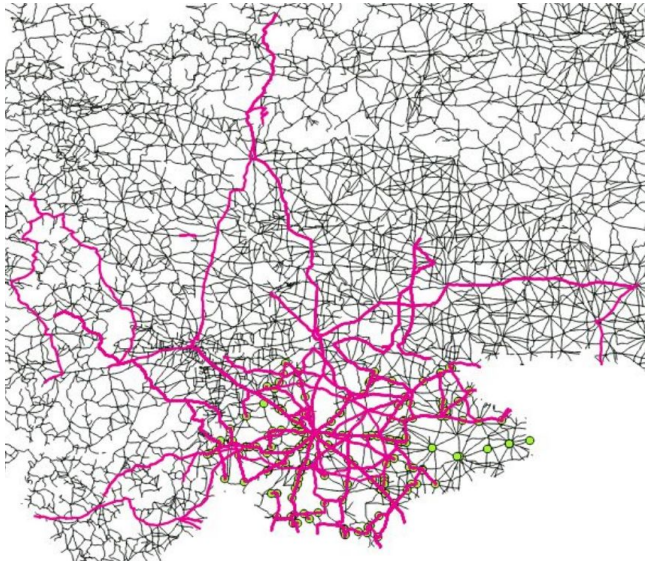
Category	EPKM Range	Trip Profitability
A	>Rs 43	15 %
B	Rs 22-43	40 %
C	<Rs. 22	45 %

Form IV populated by profitability data

senior citizen	ABC Operational Form												
	=(M12*0.07053)										Date	RIP	Time passenger earnig
18	From	To	Seating Capacity	Deparute Time	service tax	Distance	Fare	Trips Optd.	Effective Kms.	Traj Earning + Advance Booking	19	1	474
											20	1	508
951					Of						21	1	770
											22	1	573
2416	3	4	6	7	8	9	10	11	12.0	13	23	1	522
3529											24	1	501
2433	SHPR	murbad	44	5.30	7.00	42.7	54	31	1324	13486	25	1	212
	murbad	SHPR	44	7.30	9.00	42.7	54	31	1324	34255	26	1	696
	SHPR	murbad	44	9.10	6.40	42.7	54	29	1238	50034	27	1	297
3086	murbad	SHPR	44	11.00	12.30	42.7	54	29	1238	34491	28	1	1511
											29	1	253
4242	SHPR	murbad	44	13.00	14.30	42.7	54	31	1324	44580	30	1	733
2562	murbad	SHPR	44	15.00	16.30	42.7	54	31	1324	61280	31	1	243
1692	SHPR	murbad	44	17.00	18.30	42.7	54	31	1324	37019		31	13486
	murbad	SHPR	44	19.00	20.30	42.7	54	31	1324	24438			

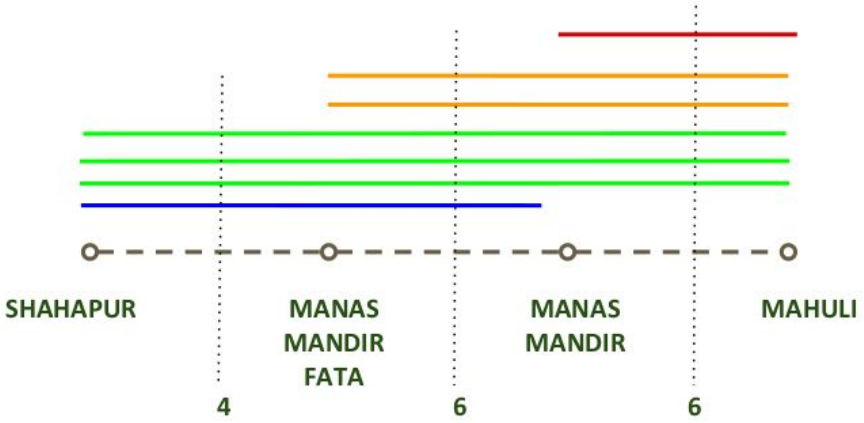
How do they look in the GIS

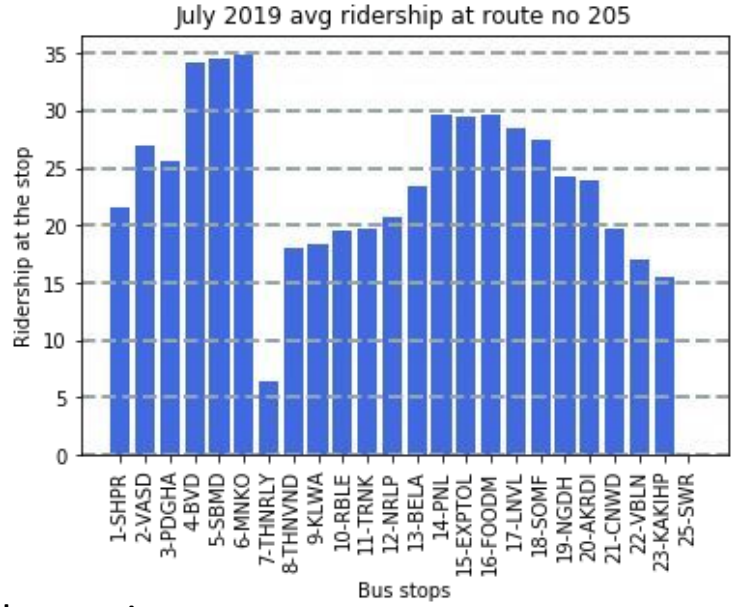




Both region and time of operation important!

Ridership - Path Analysis

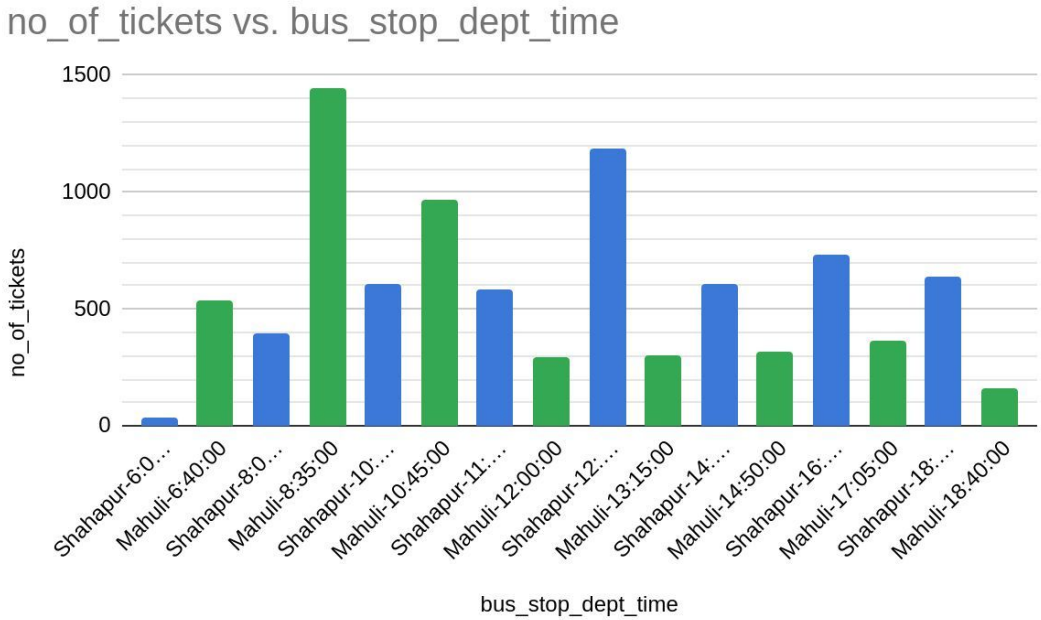




Shahapur-Pune service

1. Empties at Thane. Very few passengers take the longer journey.
2. Serves Padgha and intermediate people to reach Thane railway station. Serves as a Thane -Pune service thereafter
3. Average ridership at22 is not GOOD.

Time of Service and Directionality



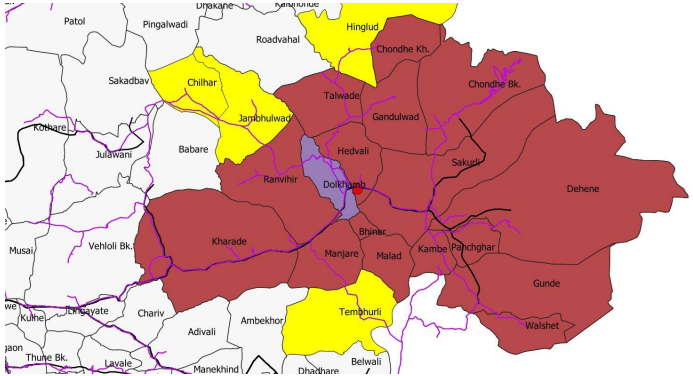
- People coming to taluka place and going back.
- How to utilize non-peak services? School services? Luggage?
- How to analyse a Schedule - Sequence of Services. **Important Optimization Problem.**

Trip-wise occupancy

route_no	trip_no	max_ridership	weighted_avg_ridership	std_dev	sitting_ridership	standing_ridership	dept_time	from_cd	till_cd	kilometer	abc_status	utilization
17526	00S81143	58	22.70	5.20	27.90	33.11	8:40:00	ASANGAON	GUNDE	41.8	B	β
17526	00S81998	65	9.47	4.25	13.72	17.97	19:15:00	ASANGAON	GUNDE	41.8	C	γ
75002	00S81310	69	14.96	7.35	22.30	29.65	19:20:00	ASANGAON	JUNAVANI	28.8	C	β
75003	00S81311	54	17.99	7.32	25.30	32.62	5:50:00	JUNAVANI	ASANGAON	28.8	C	β
75003	00S81234	29	11.26	4.69	15.94	20.63	18:05:00	JUNAVANI	ASANGAON	28.8	C	γ
92740	00S81868	73	19.92	11.21	31.12	42.33	16:30:00	GUNDE	ASANGAON	41.8	C	β

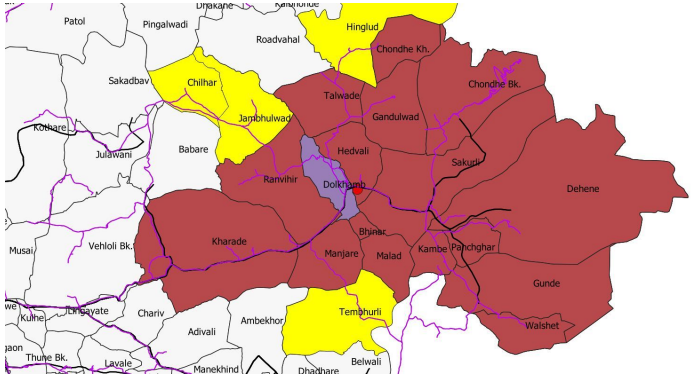
Guide discrepancy between ABC and ridership - pass-holders?

Drive bus size and capacity utilization



Analysing a school!

- What is its catchment?
- Are there buses to suit the school schedule?

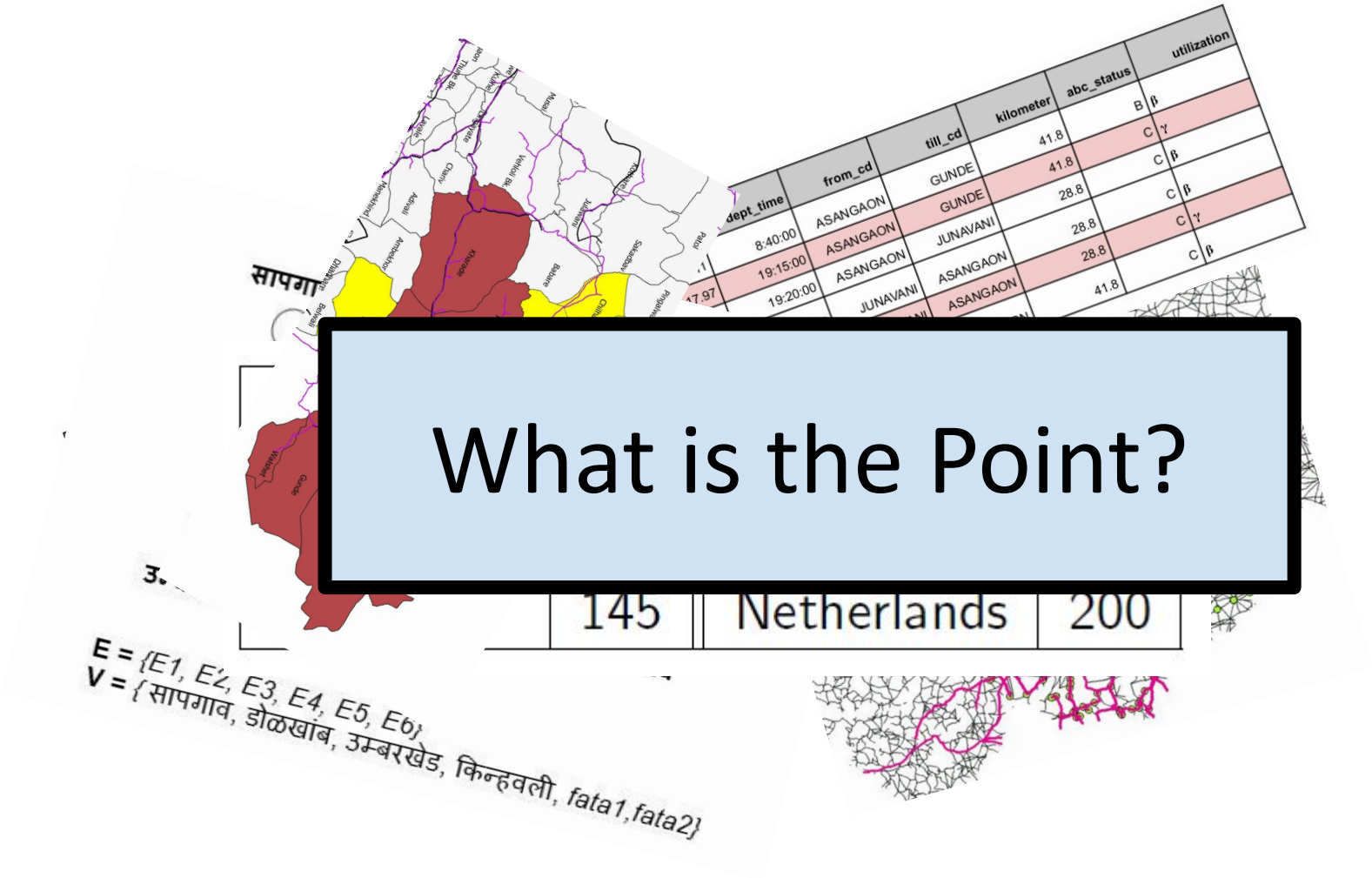


Not too good!

Bus Timings					School TImings	
Start Timing	Origin	Destination	Station	Bus Service type	Start time	10:00 AM
08:30 AM-09:45 PM	Shahapur	Chonda	Dolkhamb	Manav Vikas		
12:00 PM-01.15 PM	Shahapur	Chonda	Dolkhamb	Day Ordinary		
03:30 PM- 04.45PM	Chonda	Shahapur	Dolkhamb	Day Ordinary		
04:15 PM-05.30 PM	Shahapur	Chonda	Dolkhamb	Manav Vikas	End time	5:00 AM

So how are students coming to school?

Village Name	Distance (Village Centroid to School) (in km)			Travel Mode Choice			
	Village centroid to bus/road network	Bus/road network	Distance from bus/road network to school	Village centroid to road	Bus/road network	Distance from bus/road network to school	Remark
Jambulwad	0.408	7.203	0.103	Walk	Jeep/walk	Walk	
Ranvihir	2.482	2.085	0.103	Walk	Bus	Walk	
Bhinar	1.057	3.732	0.103	Walk	Walk	Walk	
Kharade	0.603	2.218	0.103	Walk	Walk	Walk	
Talwade	0.836	4.745	0.103	Walk	Jeep	Walk	
Malad	1.887	6.981	0.103	Walk	Walk	Walk	Road is there but no bus
Dehene	2.287	11.569	0.103	Walk	Bus	Walk	
Hinglud	1.042	7.219	0.103	Walk	Walk	Walk	
Panchghar	0.410	10.207	0.103	Walk	Bus	Walk	
Chondhe Bk.	1.250	13.303	0.103	Walk	Bus	Walk	
Chondhe Kh.	3.799	13.303	0.103	Walk	Bus	Walk	



What is the Point?

What is the Point?

India	57	China	477
Other Asia	69	Japan	506
Egypt	95	USA	306
UK	145	Netherlands	200

Per capita Steel consumption in kgs/year

We are unable to find business models or social/financial models to bring about desirable change!

Why?

- **It needs better analysis and research - better education**
- **It needs formal entry points. - better employment opportunities**

What has been shown?

It needs better analysis and research - better education

- Bringing 5-10% efficiency through improving operations
- Better social accounting and wider access
- Hi-tech fashionable areas: data, GPS, GIS, systems - Vehicle Tracking System

Needs a system-thinking approach, not merely tinkering. Needs inter-disciplinary training!

It needs formal entry points. - better employment opportunities

- Role for elite institutions to forge partnership-build engagement, do research
- Seed start-up and procure their first work-orders

Faculty members need to think differently, Institutions need to have that vision.

This has been some of the most intellectually challenging work that I could do.

For ACM-India

- Curricula which is immersive and takes students out of the class
- Focus on society and design
- Collection of standard case studies
- Faculty training

Separate the hype from where the real jobs are and where value is needed -

in India.

Students in the driver's seat!

Thank you