PASSENGER TRANSPORTATION SYSTEMS IN RURAL INDIA

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MOTIVATION

Bus Transportation Systems

- Rural Population: 0.82 billion (2007 Estimate)
- Private vehicle ownership: Very Low
- Rural Population: Predominantly captive to public transportation system
- Bus Transportation: Predominant mode of Passenger Transportation in Rural India
- Bus Transportation Network: All major roads like NH, SH and MDR
- Poor Bus Transportation Systems: A major concern

Feeder Service to Bus Stop

- Transportation Linkage between village settlements and bus stop: A Missing Component
- Recent Development of Rural Roads: 150,000 km of Rural Roads under Pradhan Matri Gram Sadak Yojana (PMGSY)
- Development of Feeder Service: An emerging need
- Planning of Feeder Service in rural areas: Little information available in the literature

Estimation of Users' Benefit

- Rational estimation: A crucial step
- Travel Disutility: Quantitative and Qualitative attributes with different units of measurement
- Transformation to a common unit: Comparison or Aggregation
- Valuing of Attributes or Willingness-to-Pay: A necessary step for estimation of users' benefit
- Valuing of travel attributes in rural India: Little information available in the literature

Improvement Planning of Rural Bus and Feeder Services with due consideration to Users' Behaviour

STUDIES ON RURAL PASSENGER TRANSPORTATION SYSTEMS

Application Areas

- Bus Transportation Systems
- Feeder Service to Bus Stop

Major Components

- Travel Behaviour Analysis: Valuing of Attributes or WTP Estimates
- Development of Generalized Cost Equations
- Application of Generalized Cost or WTP for Improvement Planning of Transportation Systems

Valuing of Attributes

Design of Survey Instrument

- Type of data: Stated Preference
- Attributes: Quantitative and Qualitative
- Preference elicitation method: Choice Based
- Preparation of Alternatives: Fractional Factorial

Model Specifications

- Multinomial Logit (MNL)
- Nested Logit (NL)
- Covariance Heterogeneity Nested Logit (CHNL)
- Random Parameter Logit (RPL)

Considerations in RPL Models

- Correlation among choice responses
- Heterogeneity studies against all observed but relevant socioeconomic and trip characteristics
- Constrained triangular distribution of random parameters

BUS TRANSPORTATION SYSTEMS

Data Collection

- Random Sampling & Personal Interview
- Identified strategic locations for wide distribution of sample

Analysis of Data

- Quantitative Attributes – Cardinal Linear form
- Qualitative Attributes – Effects coded

Attributes and their Levels: Rural Bus Systems

Attributes	Level 1	Level 2	Level 3	Level 4
Discomfort Level	1	2	3	4
Headway (min)	15	30	45	60
Travel Speed (kmph)	45	40	35	30
Travel Cost (p/km)	35	40	45	50

DL Value	Condition of Travel
1	Seating
2	Partly Standing Partly Seating
3	Standing Comfortably
4	Standing in Crowd

Econometric Models: Rural Bus System (Total Sample)

Model	MNL	RPL 1	RPL 2	RPL 3
Random parameters				
IVTT	-5.54 (19.35)	-6.56 (14.88)	-7.87 (13.63)	-6.83 (9.97)
Headway	-0.05 (10.24)	-0.05 (8.72)	-0.08 (9.16)	-0.08 (9.68)
Seating	1.20 (17.44)	1.47 (13.75)	1.71 (12.98)	1.73 (10.82)
Partly Standing Partly Seating	0.55 (7.23)	0.48 (5.59)	0.54 (6.04)	0.54 (4.45)
Stand Comfortably	-0.42 (4.36)	-0.24 (1.50)	-0.64 (3.72)	-0.70 (3.64)
Non-random parameters				
Travel Cost	-0.10 (3.05)	-0.09 (3.51)	-0.16 (5.54)	-0.18 (5.48)
Heterogeneity in mean				
IVTT : Distance	-	-	-	-0.025 (2.83)
Observations	1489	1489	1489	1489
Log Likelihood	-988.17	-987.14	-950.37	-945.55
ρ2	0.484	0.484	0.503	0.506

Willingness to Pay: Rural Bus System (Total Sample)

Attributes	IVTT (Paise*/min)	Headway (Paise/min)	Seating (Paise/km)	Part seating (Paise/km)	Standing Comfortably (Paise/km)
MNL	53.66	20.51**	11.58	5.31	-4.09
RPL 1	76.60	26.95**	17.11	5.56	-2.77(ns)
RPL 2	47.89	20.73**	10.43	3.27	-3.88
RPL 3	44.62**	19.64**	9.71	3.04	-3.91

** values are for average trip distances

Generalized Cost Model: Rural Bus System

GC = [44.62]*IVTT + [19.64]*HW + α*d + F

where

IVTT = In-vehicle travel time in minutes per km

HW = Headway in minutes

α = 0 when DL is seating

= 6.67 when DL is partly standing partly seating

= 13.62 when DL is comfortable standing

= 18.01 when DL is standing in crowd, and

F = Fare or direct travel cost in paise per km

= 350 + 36*(d-5)

d = The distance of travel in km

Alternative Improvement Scenarios

- Scenario 0: Present operating conditions
  Speed 30 kmph, Fare 36 paise/km
- Scenario 1: Conversion of some of the existing buses to accelerated services
- Scenario 2: Conversion of some of the existing buses and adding new buses as accelerated services

Accelerated service operating conditions

- Speed 40kmph
- Stopping at 16 places
- DL is Seating

Boundary Conditions

- Operational viability: Minimum operational revenue should be attained
- Capacity: At no point of the stretch a bus can carry more than 80 passengers
- Comfort: Lower level comfort kilometers (standing in comfort and standing in crowd) cannot be more than 10% of total comfort kilometers

Converted and Added Services with Fares and GC savings

Number converted	Number added	Fare		Revenue		GC savings
		Slow Ser.	Accel. Ser.	Slow Ser.	Accel. Ser.	
Scenario 1						
13	0	26	41	1909	1984	31148
15	0	25	44	1905	1914	32974
16	0	26	45	1932	2258	27617
Scenario 2						
10	4	27	44	1900	1903	31268
11	3	27	44	1911	1942	29984

Scen ario	Converted + Added buses	Fare combination	Savings in GC for Major to Major trips	Savings in GC for all other trips
1	15 + 0	S 25 - A 44	17103	15871
2	10 + 4	S 27 - A 44	15396	15871

It is recommended to convert 15 buses from the existing slow services to accelerated services

FEEDER SERVICE TO BUS STOP

Feeder Vehicles

- Tempo - Capacity 6 persons
- Trekker - Capacity 10 persons

Forms of Operation

- Fixed Schedule
- Demand Responsive
  - ✓ Dial-a-Ride
  - ✓ Dial-a-Slot

Attributes and their Levels: Feeder Service

Attributes	Levels
Fare per Km	Rs.1.00, Rs.1.50, Rs.2.00, Rs.2.50
Seating Discomfort	Comfortable Seating, Congested Seating
Access Walking Distance	0-0.5km, 0.5km-1km., 1km-1.5km, 1.5km-2km
Time Deviation	0-15min, 15-30min, 30-45min, 45-60min
Waiting Discomfort	Anxious Waiting at Stop, Relaxed Waiting at Stop, Relaxed Waiting at Home

Econometric Models (Stage-I): Feeder Service

Variable	RPL_1	RPL_2	RPL_3
Type (Random)	-0.711 (-7.88)	-0.5 (3.59)	-0.784 (8.45)
Seating Discomfort (Random)	1.649 (5.71)	2.286 (5.42)	1.256 (5.17)
Access Walking Dist. (Random)	-0.001(-3.24)	-0.002 (4.25)	-0.00088 (2.95)
Anx. Wait Time at Stop (Random)	-0.147 (-5.95)	-0.201 (5.43)	-0.125 (5.60)
Rel. Wait Time at Stop (Random)	-0.12 (-5.13)	-0.145 (4.99)	-0.105 (4.55)
Rel. Wait Time at Home (Random)	-0.097 (-5.08)	-0.118 (4.90)	-0.084 (4.46)
Cost (Non-random)	-0.075 (6.87)	-0.092 (6.24)	-0.076 (7.44)
Heterogeneity in mean, Parameter	*Variable*	HIN	MC
Type		-0.39 (2.44)	
Seating Discomfort		-0.431 (2.08)	1.483 (5.12)
Access Walking Distance		0.0013 (3.54)	-0.00076 (2.59)
Anx. Waiting Time at Stop		0.031(2.01)	-0.081 (5.16)
Rel. Waiting Time at Stop			-0.044 (2.59)
Rel. Waiting Time at Home			-0.028 (1.77)
Log likelihood function	-745.15	-724.64	-698.52
ρ^2	0.20744	0.22925	0.25704

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Willingness to Pay (Stage-I): Feeder Service

Attribute	Willingness-To-Pay (WTP)						Unit for WTP
	MNL_2	NL_5	CHNL	RPL_1	RPL_2	RPL_3	
Seating Discomfort!	44.3	33.1	33.4	43.7	49.4*/ 40.1**	71.8#/ 32.9##	Paise/Km
Access Walk Distance	49.2+	39.5+	39.8+	83.2+	143.8*+/ 56.1**+	134.9#+/ 72.3##+	Paise/Km
Anx. Wait. Time at Stop	11.8+	8.9+	8.9+	12.1+	13.7*+/ 11.6**+	17.0#+/ 10.3##+	Paise/min
Rel. Wait. Time at Stop	8.2+	6.2+	6.2+	9.9+	9.9+	12.3#+/ 8.6##+	Paise/min
Rel. Wait. Time at Home	6.8+	5.2+	5.1+	8.0+	8.1+	9.3#+ / 7.0##+	Paise/min

! WTP value is for change in level from 'congested seating' to 'comfortable seating' +The WTP estimates are for average trip length , *For high income household , ** For low income household, # For motorcycle user, ## For Cycle user

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Econometric Models (Stage-II): Feeder Service

- Separate model for motorcycle and bicycle users
- DL_{1m}: Distance traveled under comfortable seating in a vehicle
- DL_{2m}: Distance traveled under congested seating in a vehicle
- DL_{3m}: Distance traveled using motorcycle
- ISA: Individual Specific Accessibility

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Attributes	MNL_m	RPL_m
		Random parameters
DL_{1m}	-0.607 (1.729')	-0.463 (2.217)
DL_{2m}	-0.85 (2.769)	-0.787 (4.129)
DL_{3m}	-0.607 (2.115)	-0.468 (2.91)
		Non-random parameters
ISA	-0.0044 (4.826)	-0.005 (4.939)
Direct Cost of Travel	-0.0036 (3.513)	-0.0048 (5.479)
ASC Fixed-Schedule Tempo	2.0811 (2.181)	3.086 (2.962)
ASC Fixed-Schedule Trekker	3.754 (3.733)	4.827 (4.375)
ASC Dial-a-Ride Tempo	3.059 (3.4)	4.17 (4.108)
ASC Dial-a-Ride Trekker	3.428 (3.772)	4.454 (4.382)
ASC Dial-a-Slot Tempo	1.589 (1.708')	2.749 (2.775)
ASC Dial-a-Slot Trekker	3.315 (3.916)	4.412 (4.894)
Log likelihood function	-239.726	-237.92
ρ^2	0.20174	0.20776

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Generalized Cost Model: Motorcycle Users

$$GC_m = \alpha_m * D + \beta_m * ISA_m + TC$$

D= Distance traveled by motorcycle or feeder service

ISA_m = Individual Specific Accessibility

TC = Direct cost of Travel

α_m = 0 if travel is under comfortable seating in a vehicle, 67.7 if travel is under congested seating in a vehicle, and 1 if travel is by motorcycle

β_m = 1.0

$ISA_m = 134.9*AWD + \gamma_m * WT$

γ_m = 17.0 if Anxious Waiting at Stop, 12.3 if Relaxed Waiting at Stop, 9.3 if Relaxed Waiting at Home

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Generalized Cost Model: Bicycle Users

$$GC_c = \alpha_c * D + \beta_c * ISA_m + TC$$

D = Distance traveled by bicycle or feeder service

ISA_c = Individual Specific Accessibility

TC = Direct cost of Travel

α_c = 0 if travel is under comfortable seating in a vehicle, 32.7 if travel is under congested seating in a vehicle, and 155.0 if travel is by bicycle

β_c = 0.702

$ISA_c = 72.3*AWD + \gamma_c * WT$

γ_c = 10.3 if Anxious Waiting at Stop, 8.6 if Relaxed Waiting at Stop, 7.0 if Relaxed Waiting at Home

Database for Design of Feeder Service

Travel Demand to Bus Stop

[illegible]

T_i = Total trips to nearest bus stop from a village 'i'

HH_{ij} = Number of households in a village 'i' under household category 'j'

ET_j = Educational Trip rate generated by household category 'j'

HT_{ij} = Household Trip rate in a village 'i' under household category 'j'

RT_j = Revenue-generating Trip rate generated by household category 'j'

P_{ij} = Number of workers in a village 'i' under worker category 'j'

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Road Network

- Base Network
- Road Network to Bus Stop

Cutoff Revenue

- Fixed cost and Running Cost
  CR(Trekker) = 247 + 2.8 * d + P
  CR(Tempo) = 199 + 1.5 * d + P
  d is the distance traveled per day in Km and
  P is the minimum profit for operator

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MOEs for Design of Feeder Service

- Generalized Cost
- Passenger-km

Alternative Scenarios

- Scenario-I: No external subsidy or cross subsidy
- Scenario-II: External subsidy up to Rs. 20 per vehicle per day
- Scenario-III: External subsidy up to Rs. 40 per vehicle per day
- Scenario-IV: Only cross subsidy
- Scenario-V: Cross subsidy and external subsidy Rs. 20 per vehicle per day
- Scenario-VI: Cross subsidy and external subsidy Rs. 40 per vehicle per day

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Viable Fare Combinations

Fare Combinations	Fare of Trekker (Rs/km)	Fare of Tempo (Rs/km)
FC-I	1.00	1.00
FC-II	1.25	1.00
FC-III	1.25	1.00
FC-IV	1.25	1.25

Selection of Feeder Routes and Vehicle with GC as MOE

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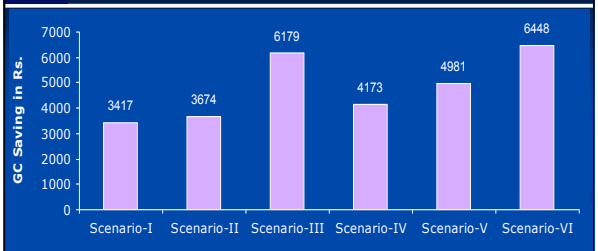

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Attributes of Feeder Service with GC as MOE

	Fare	Route Length (Km)	Pass-Km	Trekker	Tempo	Total Vehicle	Passenger Served
Scenario-I	FC-IV	43.8	16296	19	33	52	3031
Scenario-II	FC-IV	55.3	18393	18	46	64	3542
Scenario-III	FC-II	51.7	18057	21	36	57	3508
Scenario-IV	FC-III	72.3	22435	58	3	61	4709
Scenario-V	FC-III	71.4	22304	54	11	65	4704
Scenario-VI	FC-III	73.4	22379	36	36	72	4698

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Major Observations and Conclusions

- SC method applicable in rural India with low literacy rate. A sequential approach may be better if the number of alternative is more
- Travel behaviour analysis: (i) importance of selecting attribute(s) (ii) role of model specification, and (iii) need for investigating the effect of socioeconomic and trip characteristics on WTP values
- Importance of not only quantitative but also qualitative attributes in improvement planning
- Variation of WTP with model specification

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- In-vehicle time valued higher than headway by rural bus users
- Trip makers preferences towards demand responsive feeder service to bus stop
- CT distribution as an alternative to commonly used distribution in developing RPL models
- Maximizing GC savings with due consideration to operational viability- An approach for improvement of rural bus service
- Role of MOE in the selection of feeder routes and vehicle
- Cross subsidy and External Subsidy as vital policy instruments in planning of rural feeder service

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Future Research Needs and Cooperation

- Econometric Modelling, WTP Values and Norms
- Trip Rates and Forecasting of Travel Demand
- Mode Choice Behaviour
- Planning Framework and Coordination of Services

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Other Areas of Work and Cooperation

- Modelling of Traffic Congestion and Its Application
- Management of Traffic Congestion using VMS Based Traffic Information
- Parking Management
- Travel Demand Forecasting
- Mobility Pricing/Toll/User Charges

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Thank you.....