IMPROVEMENT PLANNING OF RURAL BUS SYSTEM: A CASE STUDY IN INDIA

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ABSTRACT

This paper presents the estimation of willingness to pay values using stated choice data, for various attributes of rural bus services in a developing country context, feed the same for formulation of generalised cost model as a comprehensive measure of user benefits. The generalised cost thus developed is utilised in the improvement planning of the rural bus system by evaluating various proposals that minimise the generalised cost of travel or maximise user benefits without falling short on operational viability and passenger loading.

Keywords: Rural Bus transportation, generalised cost, India.

INTRODUCTION

In developing countries like India, majority of the rural population are from low-income group with negligible private vehicle ownership. As a result, rural population are predominantly captive to public transportation system. Although some of the rural regions are well connected by the rail system, the bus system is generally considered as the lifeline in rural India. As rural population constitutes more than 70% of the country's total population, the rural bus service has a vital role to play for the economic growth of India. Rural bus system generally exhibits low travel speeds, longer headways and relatively high discomfort levels (i.e. crowding inside buses). In the recent years, bus fares have been increased at regular intervals due to frequent increase in the price of petroleum fuels all over the world. However, poor quality of bus transportation system continues. The present work demonstrates an approach for improvement planning of rural bus system with due regard to trip makers willingness to pay (WTP). A case study of a rural bus route in India is considered for this purpose.

For the estimation of WTP values, a stated choice experiment is designed and the data is analyzed using Multinomial Logit and Random Parameter Logit Model Specifications. The effect of distributional assumption of random parameters on the model goodness and WTP values is also studied. The work considers not only time and cost factors but also the soft factors such as comfort which are often ignored in the improvement planning of buses in developing countries. It is found that qualitative aspect of travel is also an important factor even in rural regions. The estimated WTP values are then used for formulating the generalized cost as a comprehensive measure of user costs. A heuristic approach is developed and demonstrated with reference to the case study for improvement planning of buses with due regard to user costs, vehicle operating costs and operational viability of the service. Although the database considered and improvement proposal investigated are case specific, the approach demonstrated can be applied for improvement planning of buses in other geographical areas giving due consideration to trip makers willingness-to-pay.

Study Area

In order to study rural bus users' WTP values for improvement in the attributes of bus system and demonstrate their use for improvement planning, a rural bus route which connects a district headquarter (Medinipur) and a tourist place (Digha) in West Bengal, India is considered. The travel demand along the study route, at the time of the study, was served by bus services only. The buses generally take about 4.5 to 5 hours to cover a distance of 137 km. and serve about 16 major stops and around 35 intermediate stops. About 42 services run between these two places with several other overlapping services. The study route is shown in Figure 1.

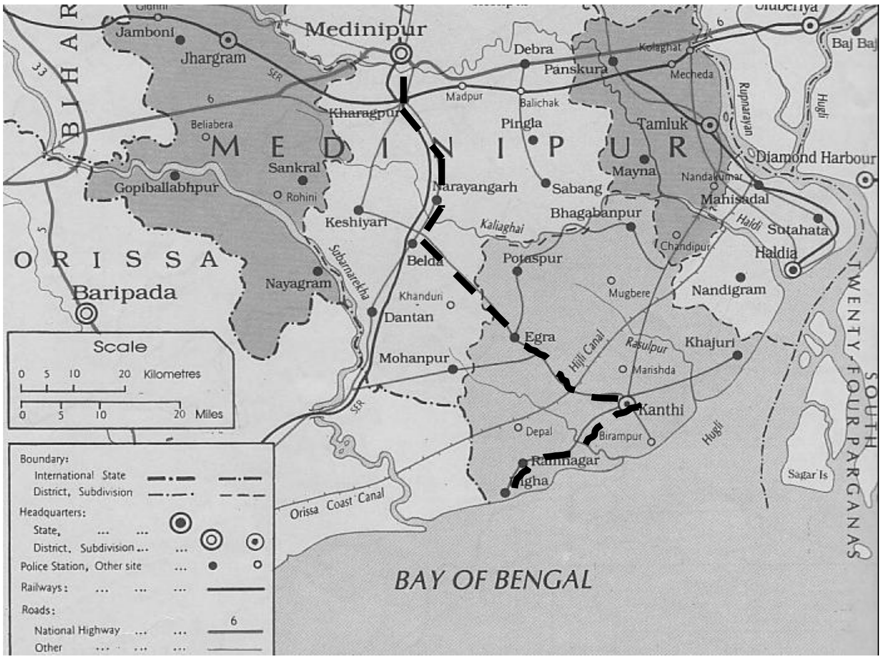

Figure 1 – Study Route in West Bengal, India

SURVEY ADMINISTRATION

Design of Survey Instrument

Survey instrument was designed for collecting respondent's trip characteristics, socio-economic characteristics and stated preference 'choices'. A questionnaire consisting of three parts was designed. The first part was to record the respondent's socio-demographic information. While the second part was to collect information related to respondent's trip characteristics. The third part was to capture respondent's 'choices' from the choice sets.

Identification of Attributes

During the preliminary investigation of the existing bus system in the study route, it was observed that the journey speeds for the buses were considerably low (about 30kmph), comfort, in terms of crowding, was less and average headway was about 20 min. The four attributes identified as having major influence on travel decision were travel time, headway, comfort and fare. Therefore, quantitative attributes like travel speed as a proxy to in-vehicle travel time (IVTT) (as the users understood 'speed' better than 'in-vehicle travel time' during discussions), travel cost, headway, and a qualitative attribute discomfort, the main characteristics of the existing bus system, were considered for the generation of alternatives for improving the existing bus system. Each attribute was described by four levels. The levels of these attributes were decided following discussions with experts and trip makers and observations from pilot survey. The attributes and corresponding levels as used in the study are shown in Table 1

Table 1 Attributes and their Levels for SC experiment

Attributes	Level 1	Level 2	Level 3	Level 4
Discomfort Level (DL)	Seating	Partly Standing Partly Seating	Stand Comfortably	Stand in Crowd
Headway (min)	15	30	45	60
Travel Speed (km/h)	30	35	40	45
Travel Cost (paisa/km)	35	40	45	50

Four attributes with four levels each would produce 4^4 (256) alternatives from full factorial technique. Therefore, fractional factorial technique with an assumption that all interaction effects are zero is adopted to reduce the number of alternatives/profiles. Fractional factorial orthogonal main effects only design using SPSS 7.5 (Hensher et. al. 2005) produced 16 alternatives using all the attributes and their levels. Presenting two alternatives at a time requires each respondent to evaluate 8 pairs which might lead to fatigue and result in loss of responses. If it is to be minimised by limiting to 4 pairs, number of respondents should be doubled which means doubling the survey efforts which has financial implications. Moreover, it is a common practice in recent times to present more than 2 alternatives in a choice set, to a respondent. The pilot survey advocated that respondents were comfortable to choose one among the five alternatives presented in a choice set. Therefore, to reduce the fatigue of respondents and to be economical, the sixteen alternatives were grouped into 4 choice sets, each containing 4 alternatives. Base alternative was also included as current alternative in each choice set as shown in Figure 2.

In the survey, a fixed experiment approach where each respondent faces exactly the same choice set at exactly the same stage of the choice task was adopted for presenting the choice sets. All the alternatives in a choice set were presented in the generic/unlabelled form (i.e. Alternative A, Alternative B etc.). Survey personnel were trained in multiple sessions to improve the quality of the work as the interviews were face to face (paper and pencil) interviews in nature. Survey personnel were equipped with pre-calculated tables to incorporate the information against travel time and fare in the SP part of the questionnaire, based on the information provided by the respondent. Along with speed, corresponding travel time between the origin and the destination given by each respondent was also presented by interviewer to improve clarity while obtaining the choices. The fare calculated based on per km cost, is presented in Rupees rounded to the nearest 25paisa. A sample of SP choice set is presented in Figure 2.

Attribute	Base (Bus)	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Comfort	Revealed	Seating	Standing Comfortably	Standing Comfortably	Part standing Part seating
Headway	Revealed	30min	15min	45min	60min
Travel Time	Revealed	*@30kph:* ___	*@40kph:* ____	*@45kph:* ____	*@35kph:* ___
Fare	Revealed	*@40p/km:*___	*@45p/km:*____	*@40p/km:*____	*@45p/km:*___
Choice					

Figure 2 Sample choice set

Data Collection and Database

The data collection stage involves collection of primary as well as secondary data. The primary data was collected through personal interviews. About 16 major stops were identified along the route to carry out the survey. Face-to-face interviews were carried out at various locations such as bus stops, market places, banks, schools, recreational spots etc. along the study route. Respondents were approached randomly. During the study, 750 respondents were approached while 475 (63%) actually participated in the survey. Each respondent was requested to provide information related to his/her socio-economic characteristics, and the most recent trip in the study route. Each respondent was then requested to choose an alternative from each of the four choice sets. This process not only gave each respondent an opportunity to evaluate all the 16 alternatives but also enriched the database with more SC observations (than the number of respondents). Additional surveys such as Boarding-Alighting and Origin-Destination surveys were also carried out at all major bus stops.

Database consists of both primary and secondary data. The primary data collected through SC surveys includes respondent's socio economic characteristics such as age, occupation, personal income, household size, household income etc., trip characteristics such as origin, destination, trip purpose, duration of the trip, fare paid etc. and SP choice. Database also includes information related to boarding-alighting and origin-destination pattern of the trip makers in the study route. The secondary data such as route and mode characteristics were collected from sources like Regional Transport Authority (RTA) and Transport agencies. Route characteristics were length of the route, number of bus stops, schedule etc. Mode characteristics include seating capacity, maintenance costs etc.

About 475 people were interviewed at various locations along the study route but responses from some people were removed due to incomplete information provided by respondents. This resulted in only 1489 refined observations for the purpose of model development.

Summary statistics of the information about trip purposes and socioeconomic details of respondents like gender, age, household income, trip purpose etc forming the database are given in Table 2

Table 2 Summary of Database

Variable	Number
Observations	1489
Male	1209
Age < 15yrs	0
15-35	694
36-60	778
> 60 yrs	17
Household Income Rs./month	
< 5000	484
5000-10000	504
10000-15000	251
> 15000	248
Job Trips	435
Business Trips	332
Recreation Trips	360
Education Trips	130

Agriculture Trips	151
Other Trips	81
Distance (in km) Mean Minimum Maximum	 44.35 5 138

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MODEL DEVELOPMENT

The data were coded according to the levels of attributes. Quantitative attributes travel time, headway and travel cost were entered the model as continuous parameters while qualitative attribute (discomfort) levels were effects coded (-1, 0, 1). The first model developed was a MNL model and later on advanced models such as RPL models were developed to see the variations with different random distributions for parameters. Attempts were made to use uniform, normal and lognormal, triangular distributions for all the parameters. When uniform distribution was applied on all the parameters the standard deviations of the 'Comfort' parameter levels have come out to be insignificant. Therefore, in the final model, only time and cost parameters are allowed to follow uniform distribution. When normal distribution was applied on all the parameters the model performance was poor. This may be due to loss of stability when all the parameters are allowed to vary (Ruud, 1996). Therefore, in the final model, only time and cost parameters are allowed to follow normal distribution. With the experience from uniform and normal distributions, all the parameters except travel time and travel cost parameters are assumed to be fixed when developing a model with lognormal distribution. Further, it was difficult to arrive at convergence when all or some of the parameters are allowed to follow triangular distribution. It was then decided to use the constrained triangular distribution. In the case of utility specification of RPL models, Ruud (1996) pointed out that Mixed (RPL) logit models have a tendency to be unstable when all parameters are allowed to vary. Fixing the cost parameter resolves this instability. If the cost parameter is allowed to vary, the distribution of a WTP parameter (say, for time) is the ratio of two distributions, a Cauchy distribution, which has no finite moments. Therefore, in the models with constrained triangular distribution travel cost was considered non-random. If the travel cost parameter is fixed/non-random then, (i) it simplifies the estimation of marginal WTP for other parameters - simple division of coefficient of attribute by coefficient of cost (ii) the distribution of the marginal willingness-to-pay for an attribute is simply the distribution of that attribute's coefficient, and (iii) to restrict the price variable to be non-positive for all individuals. All the RPL models were estimated with simulated maximum likelihood using intelligent Halton draws (Train, 1999). The models were estimated with multiple simulation runs using 25 draws, 50 draws and then 100 draws to 1000 draws with an increment of 100. It was observed that the model results got stabilized after 200 Halton draws. However, the results presented are at 500 Halton draws.

The refined observations were used for the development of utility models using LIMDEP 8.0 (2005) and BIOGEME. Table 3 shows the estimates of MNL and RPL models with various distributions for random parameters for total sample which, subsequently, are used in the application for improvement of bus transport system. RPL 1 with constrained triangular distribution and without taking into account correlations among choice responses, RPL 2 through RPL 5 use constrained triangular distribution, uniform distribution, normal distribution and lognormal distribution respectively, while taking into account correlations among choice responses across each individual. RPL 6 with constrained triangular distribution taking into account heterogeneity in the mean of the random parameter(s) which is advanced version of RPL 2.

Table 3 MNL and RPL Model Estimates

Model	MNL	RPL 1 (CTriangular)	RPL 2 (CTriangular)	RPL 3 (Uniform)	RPL 4 (Normal)	RPL 5 (Lognormal)	RPL 6 (CTriangular)
Attribute	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Random parameters							
IVTT	-5.54 (*19.35*)	-6.56 (*14.88*)	-7.87 (*13.63*)	-8.02(13.53)	-8.18(13.15)	2.02(28.11)	-6.83 (*9.97*)
Headway	-0.05 (*10.24*)	-0.05 (*8.72*)	-0.08 (*9.16*)	-0.06 (9.29)	-0.06(10.13)	-0.07(9.29)	-0.08 (*9.68*)
Seating	1.20 (*17.44*)	1.47 (*13.75*)	1.71 (*12.98*)	1.62(14.16)	1.68(11.53)	1.50(15.59)	1.73 (*10.82*)
Partly Standing Partly Seating	0.55 (*7.23*)	0.48 (*5.59*)	0.54 (*6.04*)	0.90(10.13)	0.88(9.74)	0.85(7.25)	0.54 (*4.45*)
Stand Comfortably	-0.42 (*4.36*)	-0.24 (*1.50**)	-0.64 (*3.72*)	-0.88(3.89)	-0.97(4.82)	-1.20(4.57)	-0.70 (*3.64*)
Non-random parameters							
Travel Cost	-0.10 (*3.05*)	-0.09 (*3.51*)	-0.16 (*5.54*)	-0.05 (1.32*)	-0.06(1.78*)	-2.87(7.70)	-0.18 (5.48)
Random parameter spread / std. dev.							
IVTT	-	6.56 (*14.88*)	7.87 (*13.63*)	4.05(2.52)	2.69(3.54)	0.16(2.75)	6.83 (9.97)
Headway	-	0.05 (*8.72*)	0.08 (*9.16*)				0.08 (9.68)
Seating	-	1.47 (*13.75*)	1.71 (*12.98*)				1.73 (10.82)
Partly Standing Partly Seating	-	0.48 (*5.59*)	0.54 (*6.04*)				0.54 (4.45)
Stand Comfortably	-	0.24 (*1.50**)	0.64 (*3.72*)				0.70 (3.64)
Travel Cost				0.49(7.91)	0.29(6.97)	1.50(5.53)	
Heterogeneity in mean							
IVTT : Distance	-	-	-	-	-	-	-0.025 (2.83)
Observations	1489	1489	1489	1489	1489	1489	1489
Final Log Likelihood	-988.17	-987.14	-950.37	-964.12	-962.54	-961.79	-945.55
ρ^2	0.484	0.484	0.503	0.496	0.497	0.497	0.506

* t-statistics in parenthesis

It is observed that the signs of the parameters are as expected and in agreement with the actual condition of the study route. It is evident from the t-ratios that the parameter estimates are statistically significant (except those marked with *). The overall goodness of fit is considered on the basis of ρ^2. The ρ^2 values indicate that these models are good in fit.

It may be observed from Table 3 that except 'sanding comfortably' in RPL 1 model, all attributes and/or levels are statistically significant. Decreasing log likelihood value or increasing ρ^2 values indicate that the model fits have improved from MNL to RPL 2. RPL 3 model where the time and cost parameters are allowed to follow uniform distribution has performed relatively poorly. In addition, the travel cost parameter also has become insignificant. RPL 4 model where the time and cost parameters are allowed to follow normal distribution is similar to the RPL 3 model in terms of model performance and travel cost parameter estimate. RPL 5 model where the time and cost parameters are allowed to follow lognormal distribution also has performed relatively poorly. While models with uniform and normal distributions showed that there exists taste variation in the travel time parameter, the model with lognormal distribution showed that there is a taste variation with respect to travel cost and travel time parameters. Due to relatively poor performances, the models with uniform, normal and lognormal distribution were not considered for further investigations. Moving on from RPL 2 model, in RPL 6 model, heterogeneity in the mean of the parameters was evaluated using socioeconomic characteristics like age, income, distance, etc. It is quite unusual to have no effect of income. Therefore, several attempts were made by taking personal as well as household income as continuous/two level (high & low) parameter. At one stage, it did have some impact but not as significant as the trip distance and when trip distance and income are put together, income effect has become insignificant. The final model presented in here is the one where it is found that 'travel distance' has statistically significant decomposition effect on the mean of in-vehicle travel time. The negative sign associated with it indicates that the WTP or the value of travel time is high for long distance travelers.

The interpretation of the coefficients is not straightforward except for significance. Therefore, the marginal rates of substitution between the attributes and cost are calculated. These ratios are interpreted as marginal WTP for a change in each attribute under consideration.

Table 4 presents the WTP estimates from the models (where the parameters follow constrained triangular distribution) in Table 3.

Table 4 Marginal WTP Values from Total Sample

Attributes	IVTT (Paisa*/min)	Headway (Paisa/min)	Seating** (Paisa/km)	Part seating** (Paisa/km)	Standing Comfortably** (Paisa/km)
MNL	53.66	20.51	11.58	5.31	4.09
RPL 2	47.89	20.73	10.43	3.27	3.88
RPL 6	44.62**	19.64	9.71	3.04	3.91

* 100 paisa = 1INR; 44 INR = 1 USD; ** value for average trip distance; ns – not significant.

It may be observed from Table 4 that the trip makers' WTP values for IVTT from two RPL models are lower than MNL. The pattern is same with the 'seating' and 'part seating'. For 'headway' and 'standing comfortably' no pattern is observed.

A comparison across attributes shows that, the trip makers have valued the in-vehicle travel time about 2.3 to 2.6 times greater than headway. This means that the trip makers are ready to forego nearly two and half minutes of headway against a minute saving in in-vehicle travel time or vise versa. For attribute travel discomfort, the levels 'seating' and 'part seating part standing' are positively viewed with the level 'seating' being valued nearly thrice that of the level 'part seating part standing'. This indicates that the utility gain is more (nearly three times) when the trip is made by seating than by 'part seating part standing'. 'Standing comfortably', on the other hand is valued negatively.

Accepted Model and Generalized Cost

For the models reported in Table 3, a direct test to determine whether RPL 1 and RPL 2 statistically represents the data better than the MNL model is not possible given the use of the constrained triangular distributions in the estimation of the random parameters in RPL 1 and RPL 2. This is because the spread parameter of the random parameter distribution is constrained to equal the mean of the distribution, and hence no additional parameter is estimated in the RPL 1 and RPL 2 models. Therefore, any statistical test will have zero degrees of freedom. The additional interaction term introduced to uncover mean heterogeneity in RPL 6, however, allow for tests of statistical significance between this model, the MNL model and other RPL models. The log-likelihood ratio tests are summarized in Table5.

Table 5 Log-likelihood ratio test

Test	LR	Chi-square (P=0.01)	Degrees of freedom
RPL 6 - MNL	85.24	6.64	1
RPL 6 – RPL 1	83.18	6.64	1
RPL 6 – RPL 2	9.64	6.64	1

It is evident from Table 5, that the RPL 6 model is superior statistically to the MNL model, RPL 1 and RPL 2 models. The generalized cost function is thus developed using the estimates from the accepted model (RPL 6). In the generalized cost function, the qualitative attribute levels are rescaled with respect to most desired level so that the most desired level holds zero cost and the least desired level holds maximum cost to the user. Then the Generalized Cost (in Paise) becomes,

$$\mathbf{GC = [44.62]*IVTT + [19.64]*HW + DL + F}$$

Where, IVTT equals in-vehicle travel time in minutes
HW equals headway in minutes
DL is 0 when comfort level is seating

DL is 6.67 when comfort level is partly standing partly seating
DL is 13.62 when comfort level is comfortable standing
DL is 18.01 when comfort level is standing in crowd and
F is the direct cost of travel (in Paisa) expressed as $F = 350$ if $d \leq 5$
$F = 350 + 36*(d-5)$ if $d > 5$
d is travel distance

IMPROVEMENT PLANNING APPROACH

An approach is demonstrated for evaluating improvement alternatives in the light of user benefits and operational viability. Alternatives are described by changes in relevant service characteristics, and user benefits are measured by consumer surplus (i.e. savings in total GC in this case). The improvement that maximizes the consumer surplus or overall savings in GC, and ensures operational viability, is recommended.

Survey of the Bus System

Various surveys were carried out to acquire the information for the study route. These surveys include route survey, boarding-alighting (B-A) survey, origin-destination (O-D) survey, and the bus count survey at each stop. Salient features of the study route are given below.
Route Length: 137 km
No. of Bus stops: 16 major and 35 minor
Type of Service: All stop service
Total passenger demand served: 18542 passengers; (Major stop to Major stop: 10747 passengers)
Average Travel speed: 30 km/h
No. of services between Midnapur and Digha: 42

Route Survey

The study route was surveyed extensively to identify the major stops, minor stops, overlapping routes, etc. The travel demand along the study route is served solely by bus service, which takes about 4.5 to 5 hours to cover a distance of 137 km. and serves 16 major stops and 35 intermediate stops. Presently, 42 services are being offered between Medinipur and Digha. 42 buses over a period of 14 hours results in 20 minute headway. There are several overlapping services which operate on some portions of the stretch with either origin or destination or both or none falling in the stretch.

Bus Count Survey

The number of the overlapping services and thereby the headway of the services varies at different stops along the study route. The bus count survey was carried out at several bus stops to capture the variation of headway along the study route. Because of the overlapping services, the headway is found to vary from 7 min to 20 min.

Boarding-Alighting and Origin-Destination Surveys

Boarding-Alighting (B-A) and Origin-Destination (O-D) surveys were carried out for a period of 14 hrs in a day at 16 major bus stops and some minor bus stops along the study stretch. The data collected from these surveys are used to understand the boarding-alighting and trip distribution pattern and to prepare the passenger demand matrix.

Database Development

Data collected from the surveys is used to prepare the database. Matrices prepared include demand, distance and headway. While the demand matrix gives the demand from a stop to the remaining stops, the distance matrix gives the distance between two stops, the headway matrix gives the available bus headway at different stops on the route.

Study of Alternative Improvement Schemes

It is proposed to improve the rural bus system by introducing accelerated services which will stop only at designated 16 major locations along the route, travel at a speed of 40kmph with a constant headway (depending on the number of buses being converted) all through a day and offer higher comfort (i.e. comfortable seating). While planning for accelerated services, two alternative scenarios are considered.

Scenario 1: Convert some of the existing buses to accelerated services
Scenario 2: Introduce some new buses and convert some of the existing buses to accelerated services

For each scenario several alternatives are evaluated in order to maximize the GC savings of all commuters of the route. Alternatives are formulated by changing the service attributes for both all stop and accelerated services. The analysis is carried out assuming that passenger demand at each bus stop is uniformly distributed over time and the headway of buses at each stop is also uniformly distributed.

Accelerated services are expected to attract people from the current all stop services. While evaluating alternatives for each scenario, it is necessary to ensure the operational viability of both accelerated and all stop services, and restrict the passenger loading for buses beyond the carrying capacity. The accelerated services are assumed to operate with the highest level of comfort to passengers (i.e. ‘seating’). Therefore, suitable constraints are considered while evaluating alternatives under each scenario with an objective of minimizing the GC for all commuters along the study route. The constraints are discussed below.

Minimum Revenue for bus operation (for one way trip):

Minimum revenue of Rs. 1900 is considered to be acceptable for making the services operationally viable. The minimum revenue for a one-way trip is estimated as follows.

Assuming 5 dead kilometres, fuel requirement for travelling (137 + 5) km at the rate of 5 km per litre = 30 litres
Fuel (diesel) Cost at the rate of Rs. 35 per litre = Rs. 30 x 35 = Rs. 1050.00
Driver charges = Rs. 300 per day ≈ Rs. 150 per one way trip
Attendants charges = Rs. 200 per day (Rs. 100 x 2 persons) ≈ Rs. 100 per one way trip
Other miscellaneous expenses = Rs. 300 per day ≈ Rs. 150 per one way trip
Total expenditure = Rs. 1050.00 + 150 +100 + 150 = RS. 1450.00 per one way trip
Minimum benefit to operator = Rs.800.00 per day ≈ Rs. 400 per one way trip
Total minimum revenue to make the operation viable = Rs. 1450 + Rs. 400 ≈ Rs. 1900.00 per one way trip

Capacity

Generally the seat capacity of a bus in rural regions is 55. Allowing 25 standees, the total carrying capacity of a bus is assumed as 80 passengers.

Discomfort level for a service

The DL condition may vary at different segments along the study route. But, it is necessary to assess the overall DL offered by a service over the entire study stretch. The procedure followed for assessing the DL offered by a service is discussed below.

Four comfort conditions that could be experienced by a passenger during journey are considered for estimating the WTP values. However, 'partly standing and partly seating' condition cannot be observed between two successive stops. Therefore, while calculating passenger-km under different DL conditions between two successive stops, only three DL conditions namely 'seating', 'standing in comfort' and 'standing in crowd' are considered. DL conditions for passengers are calculated on the basis of the seating capacity of a bus and the number of passengers on-board. The calculation of passenger-km under different DL conditions is mentioned below.

Let $X1_{i,i+1}$, $X2_{i,i+1}$ and $X3_{i,i+1}$ are the number of passengers experiencing the discomfort levels 'seating', 'standing in comfort' and 'standing in crowd' respectively in between two successive stops 'i' and 'i+1'. Let '$d_{i,i+1}$' is the distance between two successive stops 'i' and 'i+1', and $X_{i,i+1}$ is the number of persons onboard between two successive stops 'i' and 'i+1'.
If $X_{i,i+1} \leq 55$ then $X1_{i,i+1} = X_{i,i+1}$, $X2_{i,i+1} = 0$, and $X3_{i,i+1} = 0$
If $55 > X_{i,i+1} \leq 70$ then $X1_{i,i+1} = 55$, $X2_{i,i+1} = (X_{i,i+1} - 55)$, and $X3_{i,i+1} = 0$
If $70 > X_{i,i+1} \leq 80$ then $X1_{i,i+1} = 55$, $X2_{i,i+1} = 0$, and $X3_{i,i+1} = (X_{i,i+1} - 55)$

If there are 'n' stops along the study route, then the passenger-km served under different DL conditions are estimated as follows.

Passenger-km with 'seating' (PK1) = $\sum_{i=1}^{n-1}\left(X1_{i,i+1} * d_{i,i+1}\right)$,

Passenger-km with 'standing in comfort' (PK2) = $\sum_{i=1}^{n-1}\left(X2_{i,i+1} * d_{i,i+1}\right)$ and

Passenger-km with 'standing in crowd' (PK3) = $\sum_{i=1}^{n-1}\left(X3_{i,i+1} * d_{i,i+1}\right)$

Total passenger-km served (PK) = $\sum_{i=1}^{n-1}\left(X_{i,i+1} * d_{i,i+1}\right)$

A service is considered to be operating with 'high comfort', if (PK2+PK3) <= 0.1*PK

In the present work, each alternative is described by several attributes of all-stop and accelerated services like headway, fare and speed. The DL conditions for both services are assumed a priori. A large number of alternatives are generated for each scenario by changing all these attributes in suitable ranges. The procedure followed for evaluation of each alternative is described below. Based on evaluation, several feasible alternatives are identified. An alternative is considered as feasible if there is a GC savings to commuters with respect to the present condition, and all the three constraints are satisfied i.e. (i) revenue generation per bus is more than the minimum revenue, (ii) number of on-board passenger is not more than the capacity, and (ii) the DL conditions for both service are same as what was assumed.

Step 0: The GC per km of travel, for each individual, in the present scenario is calculated using the GC model and the matrices and then aggregated to arrive at the present system GC. Define an alternative based on attributes like headway, fare and speed separately for accelerated and all-stop services. Assume accelerated services to operate under 'high comfort'. The passenger demand matrix, distance matrix between stops, bus headway matrix at different bus stops etc. are already developed and assumed as inputs.

Step 1: Develop the shift probability matrix with each cell indicating the probability of shifting to accelerated service for travel between two major stops.

Step 2. Estimate the total passenger demand to be shifted to the accelerated service for travel between major stops. Also estimate the total passenger demand that will continue to use the slow service between major stops.

Step 3: Calculate the average passenger demands to be served per accelerated service bus at each of the major bus stops. Also calculate the average passenger demands to be served per all-stop service bus at each of the major and minor stops. The knowledge of total passenger demands estimated in Step 2 and number of buses available under all-stop and express services are used for calculating the passenger demand per bus at each stop.

Step 4: Process passenger loads at different bus stops in the sequence of their appearance along the study route. At all the major stops, loading and unloading of passenger demands are done for both all-stop and express services. At minor stops, loading and unloading of passenger demands are done only for all stop service. The number of passengers on-board per bus between any two successive stops is known at the end of Step 4.

Step 5: Calculate the passenger-km served under different discomfort conditions by each accelerated service bus along the route. Also, calculate the passenger-km served under different discomfort conditions by each all-stop service bus along the route.

Step 6: Estimate the revenue per accelerated service bus. Also, estimate the revenue per all-stop service bus. The fare structure and passenger load data are used for estimating the revenue.

Step 7: Calculate the GC per km of travel for each individual and aggregate for all passengers served by accelerated service bus to arrive at total GC for accelerated services. Also, calculate the GC per km of travel for each individual and aggregate for all passengers served by all-stop service bus to arrive at total GC for all-stop services. Finally, calculate the GC of all commuters, of the study route, by adding the total GC for accelerated services and the total GC for all-stop services accelerated and all-stop services. Consumer surplus, as the difference in the GC before improvement and after improvement, is estimated separately for slow services and improved service and then aggregated to arrive at the overall consumer surplus/user benefits.

Step 8: Check if the alternative defined in Step 0 is viable based on GC savings, operational viability, overloading (i.e. on-board passengers more than the capacity), and discomfort condition.

Evaluation of Alternative Schemes

The two scenarios described earlier are evaluated as Scenario-1 and Scenario-2. The present condition is also reported under Scenario 0: Base Case

Scenario 0: Base Case

With a fare of Rs. 0.36 per km, the revenue generated per one way trip is estimated as Rs. 2297.00. The maximum number of passengers at any point of time on a bus is 72, and the generalized cost of the system for one directional trips is Rs. 646955.00. The details of the passengers served by the current bus system are shown in Table 6.

Table 6 Details of the passengers served by the current bus system

Item	Value
Total Passengers	18542
Total Passenger km	483104

Total Pass. Avg. Travel distance in Km	26.05
Major to Major Passengers	10747
Major to Major Passenger km	304775
Major to Major Pass. Avg. Travel distance in Km	28.35
Remaining Passengers	7795
Remaining Passenger km	178330
Remaining Pass. Avg. Travel distance in Km	22.87
GC per passenger in Rs.	34.89

Scenario 1: Convert some of the existing slow services to accelerated services

Several alternatives are considered for the improvement of the existing system by converting some of the existing buses to accelerated services. The number of buses to be converted is varied between 1 and 20. However, conversion of up to 8 buses as accelerated services could not satisfy the operational viability criterion. On the other hand, with the number of converted buses beyond 16, a declining trend is observed for the GC savings. Though the entire range is analyzed, the range between 13 and 16 is presented in Table 7.

Attempts with some buses converted as accelerated services keeping the fare of remaining services same as present fare resulted in no GC savings. However, with varying fares, below the fare of existing services, there are savings in GC. The fare for the accelerated services is adjusted so that the other governing criteria are satisfying. When some buses are converted, passengers at minor stops are likely to loose some portion of GC in the form of loss due to the increased headway resulting from the conversion of buses. The headway loss at minor stops is compensated by a reduction in the fare of the slow services. In this scenario, maximum savings observed in GC is about Rs. 32974 at a fare combination of S25-A44 (i.e. fares of 25 paise/km for slow services and 44 paise/km for accelerated services) when 15 numbers of buses are converted to accelerated services. The details of the passengers served by the slow services and 15 accelerated services are given below.

	Slow Service	Accelerated Service
• No. of Passengers	17138	1404
• Passenger km	417842	65262
• Avg. Travel distance in Km	24.38	46.49
• % shift to accelerated services	13.06	
• Avg. GC per passenger in Rs.	33.11	

The above information shows that the average travel distance between major stops has increased to 46 km when accelerated services are introduced. Also the passengers shiting from slow services to accelerated services is about 13% when 15 number of slow services are converted to accelerated services.

Scenario 2: Introduce new buses and convert some of the existing buses to accelerated services

Several combinations are attempted with wide range of converted as well as added buses as accelerated services for maximizing the savings in GC of travel. Several combinations produced savings in GC of travel. However, most of them have produced GC savings nearly equal to or slightly lesser than the maximum savings of scenario 1. A combination of 10 converted from the existing services and 4 new buses added to accelerated services has produced GC savings of Rs. 31268.00 at a fare combination of S27-A44 (i.e. fares of 27 paise/km for slow services and 44 paise/km for accelerated services). The details of the passengers served by the slow services and 14 (10 converted from slow services and 4 new buses) accelerated services are given below.

	Slow Service	Accelerated Service
No. of Passengers	17306	1235
Passenger km	427364	55741
Avg. Travel distance in Km	24.69	45.13
% shift to accelerated services	11.49	
Avg. GC per passenger in Rs.	33.35	

The above information shows that the average travel distance between major stops has increased to 45 km when accelerated services are introduced. Also the passengers shiting from slow services to accelerated services is about 11%. It may be observed that in scenario-1, the percentage of people shifting to accelerated services from major-to-major passengers is expected to be 13 while in scenario-2 it is 11. In addition, GC per passenger in both the scenarios is expected to be 33. The average travel distance by new services is expected to be 46km and 45km in scenario-1 and scenario-2 respectively from 28 km of current scenario.

Selection and Recommendation

It is observed from Scenario 1 (i.e. conversion of some of existing buses as accelerated services) that conversion of 15 buses is expected to produce the maximum savings in GC. In Scenario 2 (i.e. conversion of some of the existing buses and adding some new buses) 10 converted + 4 added as accelerated services is expected to produce the maximum savings in GC. Interestingly, the maximum GC savings produced in both the Scenarios are not significantly different from each other. The details of fares for both the services, revenue generated, and GC savings in both the scenarios are shown in Table 7.

Table 7 Converted and Added Services with Fares and GC savings

		Fare		Revenue		
Number converted	Number added	Slow Ser.	Accel. Ser.	Slow Ser.	Accel. Ser.	GC savings
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

+ GC savings are with reference to present day GC

It is evident from Table 7 that conversion of existing services to accelerated services is expected to bring the maximum savings in GC when 15 numbers of buses are converted than conversion of some of the existing and adding some new services to accelerated services. It is recommended to convert 15 number of existing slow services to accelerated services. These accelerated services are to stop at 16 major stops. The fare structure for the services is 44 paise per km.

SUMMARY

This paper demonstrates improvement planning of rural bus system with due consideration to trip makers' willingness-to-pay in the context of an Indian rural region. The present work demonstrates successful applications of stated choice method for eliciting preferences and estimating WTP values with reference to a rural scenario in a developing country context. In the present day transportation in India, the qualitative aspects such as crowding in buses, noise, aesthetics etc., are not given due consideration. As a result, the operating conditions of the services are generally poor. The estimates for the qualitative attributes considered in the study not only reflects the same and but also show that the users are willing to pay for improvements in qualitative aspects emphasizing the role of qualitative attributes in transport improvements. The study shows that the model specification influences the WTP values. In addition, socioeconomic and/or trip characteristics also influence the WTP values. It is observed that the RPL specification generally produces better model performance than MNL. Within RPL models, models that account for correlations among responses have shown substantial improvement in model performance. While models accounted for heterogeneity (i.e. influence of socioeconomic or trip characteristics) also exhibit superior performance. While developing RPL models, it is necessary to assume that the random parameters follow certain distribution. Normal, lognormal, uniform and triangular distributions are the most commonly used ones for random parameters. The present work demonstrates successful applications of constrained triangular distribution that has produced a better model than the rest of the distribution.

In the present study, generalized cost is considered as a comprehensive measure of disutility comprising of both the qualitative and quantitative attributes of travel. The difference in generalized cost is the user benefits. Generalized cost in that way is also a comprehensive measure of user benefits. The use of GC for improvement planning of rural bus system is demonstrated. Taking reduction in GC as a measure for user benefits, an approach is demonstrated for maximizing user benefits with due regard to operational viability. User benefits and operational viability are the two aspects highlighted for evaluation of alternatives for improvement.

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