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Our sincere thanks to guest co-editor Dr. Jill Hough, without whom this Rural and Intercity Bus Edition would not have been possible.

Message from the Guest Editor

This special edition of the *Journal of Public Transportation* focusing on Rural and Intercity Bus commemorates the 20th National Conference for Rural Public & Intercity Bus Transportation being held October 14–17, 2012, in Salt Lake City. It also celebrates the partnership between the University of South Florida and North Dakota State University as one of the University Transportation Centers focusing on public transportation in the United States.

You will find the articles in this edition to be more applied than theoretical. Although the articles are focused on rural or intercity bus, several of the concepts and ideas can be transferable to our urban counterparts. Whether you are from a rural or an urban region, I hope that you enjoy these articles and that they spark ideas within you for further research and outreach to benefit the public transportation industry.

Thanks for reading.

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CONTENTS

Multivariate Statistical Analysis of Public Transit Bus Driver Distraction

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Abstract

This paper examines the efficacy of a multivariate statistical modeling approach to analyze public transit bus driver distraction data collected through a self-administered driver survey. The distracting activities were classified into four risk zones according to distraction risk indices derived from distracting ratings, distracting durations, and driver perception of risks. A multinomial logistic regression model was formulated for highly-risky distracting activities using levels of distraction as the categorical dependent variable and correlating it with categorical and continuous independent variables responsible for the distraction. Results revealed that the common sources of distraction were due to passenger-related activities, which match two-thirds of simulated validation outputs. On-site route observations and discussions with transit staff revealed mixed results. The model could be used to identify drivers at highest distraction risk from their demographic backgrounds as well as driving schedules. The transit agency can use the results to implement relevant policies and training programs to mitigate distraction and improve transit performance.

Introduction

Over the past few years, distracted driving accidents have increased due to the proliferation of electronic devices use while driving and greater driver involvement in secondary tasks (U. S. DOT 2009). Research on transit bus driver distraction conducted in the U. S. is limited (D'Souza and Maheshwari 2012a and 2012b), although sources of distraction are generally higher due to the driver performing required secondary tasks and attending to many passengers. The National Transit Database (NTD) was used to study the relationship between transit bus collisions and factors such as road design, weather, lighting, etc. (Yang 2007), but driver distraction was not included as a factor in this study. Due to lack of distraction-reporting by transit drivers, the associated risks and impact on performance is difficult to study and is not well-understood.

The increasingly complex nature of distraction data that consist of multiple predictors and categorical outcome variables requires an appropriate multivariate statistical model to relate the levels of distracting activities with factors that impact distraction. Multinomial logistic regression (MLR) or multinomial logit (MNL) models are widely used in transportation to study relationships between categorical dependent variables and sets of continuous and/or categorical independent variables (Washington et al. 2011; Yan et al. 2009; Morfoulaki et al. 2007; Gkritza et al. 2006).

This paper attempts to establish the likelihood that a transit bus driver's risk of getting distracted is related to his/her demographic background, driving hours per week, and location. It is based on an exploratory distracted-driving study conducted at a regional public transit agency serving six cities and surrounding suburbs within an area of 369 square miles and an annual ridership of 18 million. The distracting activities identified from a survey were classified into risk zones according to distraction risk indices derived from distracting ratings, distracting durations, and driver perception of risks. The MLR was used to model highly-risky distracting activities using levels of distraction as the categorical dependent variable and correlating it with driver demographics, location, and driving load as independent variables. The independent variables were identified from the literature review (Salmon et al. 2011), discussions with the transit agency, and sample route observations. Comparison of the MLR model's results with the simulated outputs show similarities for two-thirds of the model values. On-site field observations and discussions with transit staff were conducted to verify the discrepancies between MLR model and simulated results.

The remainder of this paper is organized as follows. The next section develops a Distraction Risk Index to classify distracting activities into their respective risk zones. This is followed by MLR modeling of highly-risky distracting activities and interpretation of results. The results are statistically assessed and validated using Monte Carlo simulation and on-site route observations. The last section concludes the paper and discusses some of the applications and limitations.

Classification of Distraction Activities

Data Collection and Analysis

The survey instrument used by Salmon et al. (2006) was redesigned to collect data on driver demographics, driving pattern, source, duration and perception of distraction. The survey was approved by the transit agency and the Hampton University Institutional Review Board (IRB). This self-administered survey was conducted during the summer of 2011 on a group of drivers located in the transit agency's Northside and Southside operation centers. The region was divided into two areas: the Northside and Southside due to the difference in population density, street layouts, and accident rates. The Southside is more commercialized and densely populated with a higher accident rate of 62 accidents/million miles compared to the Northside's rate of 54 accidents/million miles.

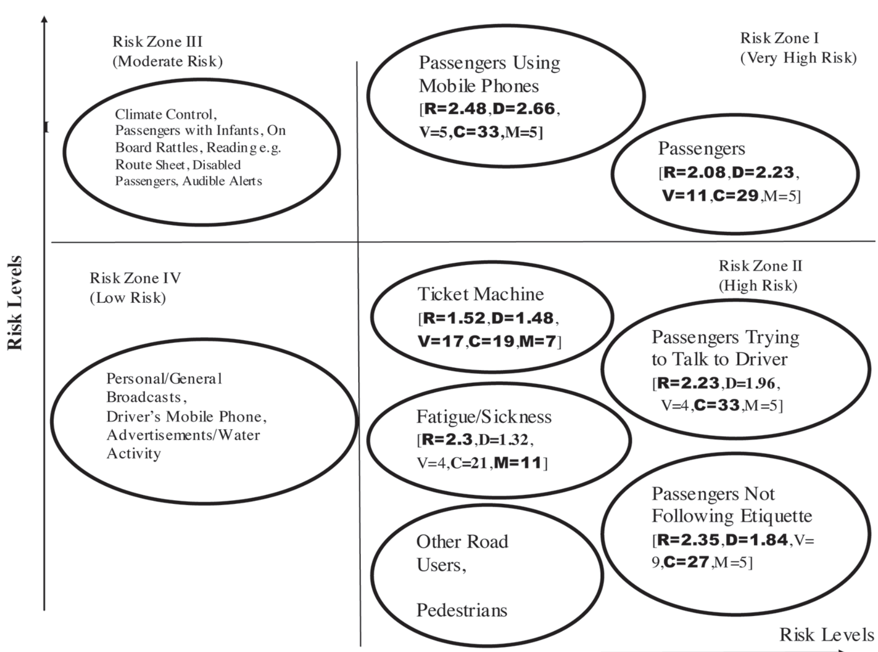
Completing the survey was voluntary, requiring the driver's written consent and assurance of confidentiality of their responses. An agency representative was assigned to distribute the surveys, deliver the introduction, answer questions, and assist in the survey process. A total of 265 surveys were distributed to 100 drivers on the Northside and 165 on the Southside. A total of 48 (19 from the Northside and 29 from the Southside) completed surveys were returned, resulting in an 18 percent response rate. The survey responses reflected the perception of the drivers who were the primary sources for distraction information. Their responses were fairly consistent and comparable with other transit bus surveys (Salmon at al. 2006).

The transit bus drivers rated how distracting they found listed activities and the approximate duration they experienced these activities in a typical eight-hour shift (Salmon at al. 2006). The ratings and durations for each activity were averaged and ranked from highest to lowest. Each distracting activity's rating and duration were graded as a percentage (%) relative to the highest rating (2.48) and highest duration (2.66 hours).

The U.S. Department of Transportation (2010) has categorized distractions as Visual, Manual, and Cognitive and reported that the severity of distractions increases as it involves more than one category. The bus drivers were asked to categorize each distracting activity according to their perception. The total responses from the bus drivers were ranked from highest to lowest. The number of driver responses for distracting activities in each category was graded as a percentage (%) relative to the highest visual (19 driver responses), cognitive (33 driver responses), and manual (11 driver responses).

Development of the Distraction Risk Index

The graded scores for rating and duration of distraction, visual, cognitive and physical distractions are summarized in Table 1. The graded scores of each distracting activity were averaged to produce the Distraction Risk Index (DRI) that measures the potential risk associated with each risk zone activity. The DRIs ranged from 31–74 percent (excluding "Others"), with a mean of 56.77 percent and standard deviation of 11.5 percent. Following the approach of Peng and Nichols (2003), distracting activities scoring a DRI of at least one standard deviation above the mean, i.e., 70 percent or higher were identified as Risk Zone I (very high risk) activities. Those scoring between 60 and 69 percent were identified as Risk Zone II (high risk) activities. Similarly, the range for Risk Zone III (moderate risk) activities was set at DRI scores between 50 and 59 percent, and the range for Risk Zone IV (low risk) was set at DRI scores below 50 percent. The graded scores of all distracting activities with the DRIs and assigned risk zones are shown in Table 1. Two distracting activities were classified into Risk Zone I, six into Risk Zone II, six into Risk Zone III, and remaining five into Risk Zone IV (Figure 1).



R = Distracting Rating; D = Distracting Duration; V = Visual Perception; C = Cognitive Perception; M = Manual/Physical Perception. The respective values are obtained from final study report. Bolding indicates the values are critical for the assigned Risk Zone. The position of distracting activities within each quadrant is not related to its risk level.

Figure 1. Classification of Distracting Activities into Risk Zones

Table 1. Graded Scores and Distraction Risk Index for Each Distracting Activity

Distracting Activities	Distraction Rating (% of highest)	Distraction Duration (% of highest)	Eyes Off Road (% of highest)	Mind/Attention Off Road (% of highest)	Physical Interference (% of highest)	Avg. (Distraction Risk Index)	Risk Zone
Passengers Using Mobile Phones	100%	100%	26%	100%	45%	74%	I
Passengers (Moving Around, Standing Next to Driver's Cabin, Talking Next to Driver's Cabin)	84%	84%	58%	88%	45%	72%	I
Passengers Not Following Etiquette (Eating, Drinking, Smoking, Noisy)	95%	69%	47%	82%	45%	68%	II
Passengers Trying to Talk to Driver	90%	74%	21%	100%	45%	66%	II
Ticket Machine	61%	56%	89%	58%	64%	66%	II
Fatigue/Sickness	85%	50%	21%	64%	100%	64%	II
Other Road Users	79%	84%	32%	64%	55%	63%	II
Pedestrians	71%	69%	42%	64%	64%	62%	II
On-Board Rattles	75%	68%	37%	67%	36%	57%	III
Passengers with Infants	76%	59%	47%	82%	18%	56%	III
Climate Controls	56%	34%	58%	52%	64%	53%	III
Reading (e.g., Route Sheet)	57%	27%	100%	45%	27%	51%	III
Passengers with Disabilities	56%	38%	47%	52%	64%	51%	III
Audible Alerts	67%	46%	21%	79%	36%	50%	III
General Broadcasts	71%	57%	5%	85%	27%	49%	IV
Personal Broadcasts	67%	48%	21%	67%	36%	48%	IV
Driver Mobile Phone	64%	28%	26%	52%	27%	39%	IV
Advertisements/Water Activity	51%	24%	16%	48%	18%	31%	IV
Others (please specify)	20%	6%	5%	27%	9%	13%	IV

Modeling Distracting Activities

The research hypotheses were to determine the likelihood that the public transit bus driver getting slightly distracted, distracted, and very distracted with respect to not distracted is related to his/her demographic background, driving hours/week, and location. The MLR model was applied to eight distracting activities classified in Risk Zone I and II (Figure 1) to identify the factors having significant impact on the levels of distraction. The MLR model provides estimates of the sign of the independent variable coefficients and their magnitude relative to one another, the odds ratios (Yan et al. 2009; Morfoulaki et al. 2007; Peng and Nichols 2003), and the probability of occurrence of a distraction level relative to a reference distraction level (Field 2009; Yan et al. 2009).

The categorical dependent variable has four levels: Not Distracted, Slightly Distracted, Distracted, and Very Distracted. The independent variables included categorical variable—gender and location—and continuous variables—age, driving experience, and driving hours per week. This concept of categorizing distraction is similar to the one used by Morfoulaki et al. (2007) to identify the factors contributing to service quality and customer satisfaction (Very Satisfied, Satisfied, Somewhat Dissatisfied, and Very Dissatisfied) with a public transit service in Greece.

The MLR model for highly-risky distracting activities in Risk Zone I and II was converted into binary logistic regression models, with each response variable level compared to a reference level (Moutinho and Hutcheson 2011). Hence, four distracting levels (k = 4) produced three (k – 1) binary logistic regression models for each distracting activity. The general MLR model proposed by Moutinho and Hutcheson (2011) is expressed as:

$$log\left(\frac{\Pr(Y=j)}{\Pr(Y=j')}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots . + \beta_k X_k \quad (1)$$

Where,

j is the identified distraction level and j' is the reference distraction level.

$X_1, X_2, \ldots\ldots X_k$ are the categorical or continuous independent variables.

β_0 is the Y axis intercept (constant term) and $\beta_1, \beta_2, \ldots\ldots \beta_k$ are the common slope coefficients.

Logit model 2 comparing Slightly Distracted with Not Distracted is stated as:

$$log\left(\frac{\Pr(Y=Slightly\ Distracted)}{\Pr(Y=Not\ Distracted)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots . + \beta_k X_k \quad (2)$$

Logit model 3 comparing Distracted with Not Distracted is stated as:

$$log\left(\frac{\Pr(Y = Distracted)}{\Pr(Y = Not\ Distracted)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots . + \beta_k X_k \quad (3)$$

Logit model 4 comparing Very Distracted with Not Distracted is stated as:

$$log\left(\frac{\Pr(Y = Very\ Distracted)}{\Pr(Y = Not\ Distracted)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots . + \beta_k X_k \quad (4)$$

The logit models 2, 3, and 4 provide three estimates of the impact each independent variable has on the dependent variable, allowing the impact of independent variable X_k to be computed for each logit model and for the whole model.

For modeling the transit bus driver distraction, the multinomial dependent variable Y_i (*logit*), which measures the total contribution of the five factors (independent variables), is expressed as:

$$Y_i = \beta_0 + \beta_1 * LOCAT + \beta_2 * SEX + \beta_3 * AGE + \beta_4 * EXP + \beta_5 * DRIVING/WK \quad (5)$$

Where,

LOCAT: Location of driver, a categorical variable, 1 = Northside, 2 = Southside.
SEX: Gender of driver, a categorical variable, 1 = Male, 2 = Female.
AGE: Reported age of driver in years, a continuous variable.
EXP: Number of years of experience driving a bus, a continuous variable.
DRIVING/WK: Weekly driving hours, a continuous variable.

The parameters β_0, β_1, β_2, ... β_k are estimated by the maximum-likelihood method, which maximizes the likelihood of reproducing the data with a given parameter estimate (Field 2009; Peng and Nichols 2003).

The coefficients estimated by the MLR models are used to predict the probability of a driver getting distracted relative to the reference level (Not Distracted). In logistic regression, the dependent variable Y_i in Equation (5) is a logit, which is the natural log of the odds ratio.

Taking the antilog of the logit (Y_i) and natural log of the odds ratio results in the following binary logistic function (Field 2009):

$$f(Y_i) = \left(\frac{1}{1 + e^{-y_i}}\right) \quad (6)$$

Where,

$f(Y_i)$ is the probability of a driver getting Slightly Distracted, Distracted, or Very Distracted.

e = 2.71828 is the base of natural logarithms.

A distracting activity is very unlikely to occur if $f\,(Y_i)$ is close to 0 and very likely to occur if it is close to 1.

Equations (2), (3), and (4) were fitted to the survey data using SPSS 17.0 (2008) to test the hypothesis stated in the Modeling Distracting Activities section. SPSS 17.0 (2008) included all the independent variables as direct entry. A stepwise (MLR) procedure then eliminated non-significant variables until a good fit was achieved with the significant variables. The MLR output is split into three tables since the categorical dependent variables are compared in pairs. The analysis was conducted for each of the eight distracting activities in Risk Zones I and II (Figure 1) to estimate the function Y_{ij} (*logit*) of the MLR model that best fits the data for each distracting activity. Out of eight MLR models developed for Risk Zones I and II activities, six were found to be highly significant ($p < 0.05$) and exhibited a good fit (Table 2).

Table 2. MLR Model Functions for Risk Zone I and II Activities

Activity	Slightly Distracted (2)	Distracted (3)	Very Distracted (4)
Passengers Using Mobile Phone (1)	(Y12)* = -105.49 – 9.48 LOCAT + 82.41SEX+1.65AGE +2.57EXP+1.89DRIVING/WK	(Y13) = 156.58 – 5.82LOCAT + 20.06SEX – 2.72AGE +3.67EXP – 3.79DRIVING/WK	N/S**
Passengers (2)	(Y22) = – 2.20LOCAT + 16.05SEX+0.13DRIVING/WK	(Y23) = -224.35 + 235.99SEX +0.20EXP+4.53DRIVING/WK	(Y24) = 0.47DRIVING/WK
Fatigue/Sick (3)	N/S	N/S	(Y34) = 137.74SEX
Passengers Not Following Etiquette (4)	(Y42) = – 4.47LOCAT + 53.49SEX	(Y43) = 323.22 – 6.52LOCAT -6.26AGE -7.99DRIVING/WK	(Y44) = 152.61SEX
Ticket Machine (5)	(Y52) = 1050.21 – 11.51LOCAT - 68.67SEX-20.30AGE +23.86EXP-26.51DRIVING/WK	N/S	N/S
Other Road Users (6)	(Y62) = 55.88 – 1.28DRIVING/WK – 1.04AGE	N/S	(Y64) = 67.26 – 2.66DRIVING/WK – 1.93AGE
Passenger Trying to Talk To Driver (7)	N/S	N/S	N/S
Pedestrians (8)	N/S	N/S	N/S

Note: SPSS 17.0 sets the reference level Not Distracted = 0 with Slightly Distracting (2), Distracting (3), and Very Distracting (4) set = 1; Northside = 1 and Southside = 0; Male = 1 and Female = 0.
**(Yij) is the estimated function that measures the total contribution of each significant factor where, i = 1 to 6, j = 2 to 4.*
*** MLR Final Model or individual independent variables were not significant (N/S).*

Model Assessment and Validation of Results

Model Assessment

Due to space limitation, only model assessment for "Passengers" is presented in Table 3. The likelihood ratio test using model fitting information shows that the difference in the -2Log Likelihood between the intercept only (without any independent variables) and the final model (with all the independent variables) provides the chi-square (χ^2) = 36.61 (18) signifying a good improvement in the model fit. It follows that the independent variables contribute significantly to the outcome variable. The values of the AIC initial/final values (114.22/104.16); the BIC initial/final values (145.06/140.14) get smaller during the stepwise process indicating a good fit for the final model.

The model's Goodness of Fit as indicated by the p-values for Pearson and Deviance chi-square (χ^2) = 1.00, (p = 1), indicating that the predicted values of the model are not significantly different from the observed values at all outcome levels i.e., the model fits the data well. The measures of Pseudo R2 (0.59, 0.65, and 0.32) are reasonably high values and when used as supplementary tests (Peng and Nichols 2003) also indicates a good fit. Table 3 presents the outputs from three binary logistic regression models along with the coefficients (β), Wald Statistic, and odds ratios (Exp [B]), along with the 95% Confidence Interval (CI) values.

Interpretation of MLR Results for High Risk Distracting Activities

Out of the eight distracting activities in Risk Zone I and II shown in Table 2, six significant activities were analyzed for impact of the sign and magnitude of the significant independent variable's coefficients on the dependent variable. In the interest of space, interpretation of results for very high risk distracting activity "Passengers" is illustrated here and results for the remaining activities are summarized in Table 4.

The MLR model functions Y_{ij} (*logit*) for "Passengers" distracting levels are reproduced from Table 2 as follows:

Slightly Distracted: $(Y_{22}) = -2.20LOCAT + 16.05SEX + 0.13DRIVING/WK$ (7)

Distracted: $(Y_{23}) = -224.35 + 235.99SEX + 0.20EXP + 4.53DRIVING/WK$ (8)

Very Distracted: $(Y_{24}) = 0.47DRIVING/WK$ (9)

Table 3. MLR Model Parameter Estimates for "Passengers"

Model Chi-Square ($\chi 2$) = 36.61 (18)*** Pearson Stat (NS) Deviance Stat(NS)	R2 = 0.590 (Cox & Snell); 0.649 (Nagelkerke); 0.317 (McFadden)	AIC initial/final values: 114.22/104.16 BIC initial/final values: 145.06/140.14		
Independent Variables and Interactions	**Coeff β (SE)**	**Wald Statistic**	**Odds Ratio Exp (B)**	**95% CI**
Slightly Distracted vs. Not Distracted				
Intercept	N/S	-		
LOCAT = 1	-2.20 (1.04)**	4.44	0.11	[0.14 – 0.86]
LOCAT = 2	0.00			
SEX =1	16.05 (6.04)**	7.07	9340926	[67.82 – 1.29E12]
SEX = 2	0.00			
AGE	N/S	-	N/A	
EXP	N/S	-	N/A	
DRIVING/WK	0.13 (0.07)*	3.64	1.14	[1.00 – 1.30]
AGE*DRIVING/WK	N/S	-	N/A	
SEX=1*DRIVING/WK	-0.34 (0.13)****	6.87	0.71	[0.55 – 0.92]
AGE*EXP	N/S	-	N/A	
Distracted vs. Not Distracted				
Intercept	-224.35 (6.95)****	1042.79		
LOCAT = 1	N/S	-	N/A	
LOCAT = 2	0.00			
SEX =1	235.99 (1.53)****	23736	3.08E102	[1.53E103 – 6.20E103]
SEX = 2	0.00			
AGE	N/S	-	N/A	
EXP	0.20 (0.10)**	3.79	1.22	[1.0 – 1.48]
DRIVING/WK	4.53 (0.10)****	1947	93.15	[76.16 – 113.94]
AGE*DRIVING/WK	N/S	-	N/A	
SEX=1*DRIVING/WK	N/S	-	N/A	
AGE*EXP	N/S	-	N/A	
Very Distracted vs. Not Distracted				
DRIVING/WK	0.47 (0.21)**	5.00	1.6	[1.06 – 2.41]

**p < 0.10; **p < 0.05; ***p < 0.01; ****p < 0.001. N/S = Not Significant.*

Table 4. Impacts of Independent Variable Coefficients on Risk Zone I and II Distracting Activities Relative to Not Distracting Activity

High Risk Activity	Location	Sex	Age	Driving Exp	Driving Hrs/Wk
Passengers Using Mobile Phone	Southside drivers are more likely to get Slightly Distracted, followed by Distracted.	Male drivers are more likely to get Slightly Distracted, followed by Distracted.	Older drivers are more likely to get Slightly Distracted but less likely to get Distracted.	Drivers with more driving experience are more likely to get Slightly Distracted, followed by Distracted.	Drivers doing more driving hours are more likely to get Slightly Distracted but less likely to get Distracted.
Passengers	Southside drivers are more likely to get Slightly Distracted.	Male drivers are more likely to get Distracted, followed by Slightly Distracted.	N/S	Drivers having more driving experience are more likely to get Distracted.	Drivers doing more driving hours are more likely to get Distracted, followed by Very Distracted, or Slightly Distracted.
Fatigue/Sickness	N/S	Male drivers are more likely to get Very Distracted.	N/S	N/S	N/S
Passengers Not Following Etiquette	Southside drivers are more likely to get Slightly Distracted, followed by Distracted	Male drivers are more likely to get Very Distracted, followed by Slightly Distracted	Older drivers are less likely to get Distracted.	N/S	Drivers doing more driving hours are less likely to get Distracted.
Ticket Machine	Southside drivers are more likely to get Slightly Distracted.	Female drivers are more likely to get Slightly Distracted	Older drivers are less likely to get Slightly Distracted.	Drivers having more driving experience are more likely to get Slightly Distracted.	Drivers doing more driving hours are less likely to get Slightly Distracted
Other Road Users	N/S	N/S	Older drivers are less likely to get Slightly Distracted, followed by Very Distracted.	N/S	Drivers doing more driving hours are less likely to get Slightly Distracted, followed by Very Distracted.
Passengers Trying To Talk To Driver	N/S	N/S	N/S	N/S	N/S
Pedestrians	N/S	N/S	N/S	N/S	N/S

N/S – MLR models were not significant.

Location

SPSS 17.0 (2008) coded Northside = 1 and Southside = 0 and used Not Distracted as the reference level. The negative coefficient (-2.20) associated with LOCAT in Equation (7) implies that holding all other independent variables constant, the Southside drivers were more likely than their Northside counterpart to get Slightly Distracted by passengers. The odds ratio (0.11) is < 1, and the 95% CI does not include 1 (Table 3), which indicates less likelihood of a Northside driver getting Slightly Distracted than a Southside driver. The odds of a Northside driver getting Slightly Distracted compared to the odds of Not Distracted by passengers are 0.11. The reciprocal of 0.11 indicates that drivers in the Northside were 9 times more likely to get "Not Distracted" than "Slightly Distracted." The Northside had a lower population density than the Southside and, hence, fewer passengers, which could possibly lead to less passenger distraction.

Gender

SPSS 17.0 (2008) coded Male = 1 and Female = 0 and used Not Distracted as the reference level. The positive coefficients (16.00 and 235.99) associated with SEX in Equations (7) and (8) implies that holding all other independent variables constant, male drivers were more likely than female drivers to get Distracted, followed by Slightly Distracted by passengers. The estimation of separate coefficients for both functions indicates that gender is not considered equally in the functions (Washington et al. 2011), with Distracted having the highest likelihood, followed by Slightly Distracted. The odds ratios are > 1, and the 95% CI does not include 1 (Table 3), which indicates greater likelihood of a male drover getting Distracted, followed by Slightly Distracted than female drivers. The odds for the male drivers getting Distracted to Slightly Distracted compared to the odds of Not Distracted by passengers are very high values (Table 3).

Driving Hours/Week

SPSS 17.0 (2008) used Not Distracted as the reference level. The positive coefficients (0.13, 4.53, and 0.47) associated with DRIVING/WK in Equations (7), (8), and (9) implies that, holding all other independent variables constant, the higher the driving hours/week, the more likely the driver would get Distracted, followed by Very Distracted and Slightly Distracted. The estimation of separate coefficients for the three functions indicates that driving hours/week is not considered equally in the functions with Distracted having the highest likelihood, followed by Very Distracted and Slightly Distracted. The odds ratios are > 1 for all three functions, and the 95% CI does not include 1 for Distracted and Very Distracted, but for Slightly

Distracted the lower limit of the CI is 1; hence, it was considered as "not including" 1 (Table 3). If a driver increases his/her driving hours/week by one hour, the relative risk of getting Slightly Distracted, Distracted, and Very Distracted relative to Not Distracted would increase by 1.14, 93.15, and 1.60 times, respectively, given the other independent variables are held constant.

Driving Experience

SPSS 17.0 (2008) used Not Distracted as the reference level. The positive coefficient (0.20) associated with EXP in Equations (8) implies that, holding all other independent variables constant, the higher the driving experience, the more likely the a driver would get Distracted. The odds ratios are > 1, but the lower limit of the CI is 1, i.e., the odds ratio will be significant at any confidence level of alpha > 0.05 (Table 3). Hence, for this analysis it is considered significant. If a driver increases his/her driving experience by one year, the risk of getting Distracted relative to Not Distracted would increase by 1.22 times, given the other independent variables are held constant. This appears contrary to popular belief, where experience made a driver better at handling distraction. There was a significance difference in driving experience in both locations, with drivers on the Southside having more driving experience (15 years) as compared to the Northside drivers (8 years). It must be noted that the more experienced Southside drivers also have a high accident rate.

The above interpretation for "Passengers" covered significant independent variables LOCAT, SEX, DRIVING/WK, and EXP. The variable AGE was not significant for "Passengers" but is an important factor related to accidents, with younger drivers more prone to distracted driving and accidents (U. S. DOT 2009). This study reveals the positive and negative impact of age on other distraction activities, which are discussed in D'Souza and Maheshwari (2012a and 2012b).

The impact of coefficients of all MLR functions listed in Table 2 is summarized in Table 4. Following the approach of Washington et al. (2011), for functions having separate coefficients, interpretation is provided only for the largest positive or smallest negative coefficient.

Validation of MLR Results

The MLR model functions for the Risk Zones I and II activities provide estimates of the current levels of distraction at the transit agency. How effective are these functions, and how can one validate these results? Are the results generated from the MLR models for each risk zone activity valid for a large random population of transit bus drivers? Simulating the models using probabilistic distributions generates driver distraction events that would occur in practice over a range of random factors. Monte Carlo simulation using discrete distribution that incorporates random variability into the model was applied to validate the results. Each MLR function in Table 2 was simulated for a large sample of drivers with randomly selected location, age, sex, driving experience, and driving hours/week.

Following the approach of Smith et al. (2005), these five independent variables were simulated for 1,000 replications one at a time, keeping the remaining variables constant. The impact of independent variables' coefficients (Table 4) were validated by comparison with the simulated probability values. For each Risk Zone I and II activity, the simulation model generated average probability values from Equation (6) for 1,000 drivers getting Slightly Distracted, Distracted, and Very Distracted by the distraction factors. The results for location, gender, and driving hours/week related to distracting activity "Passengers" are presented as follows.

Location

The MLR model results presented in Table 4 indicate that the Southside drivers have a higher likelihood of getting Slightly Distracted and Distracted. The simulation output (Figure 2) validates these results for all the passenger-related activities. The probability values for Southside drivers are higher compared to Northside drivers.

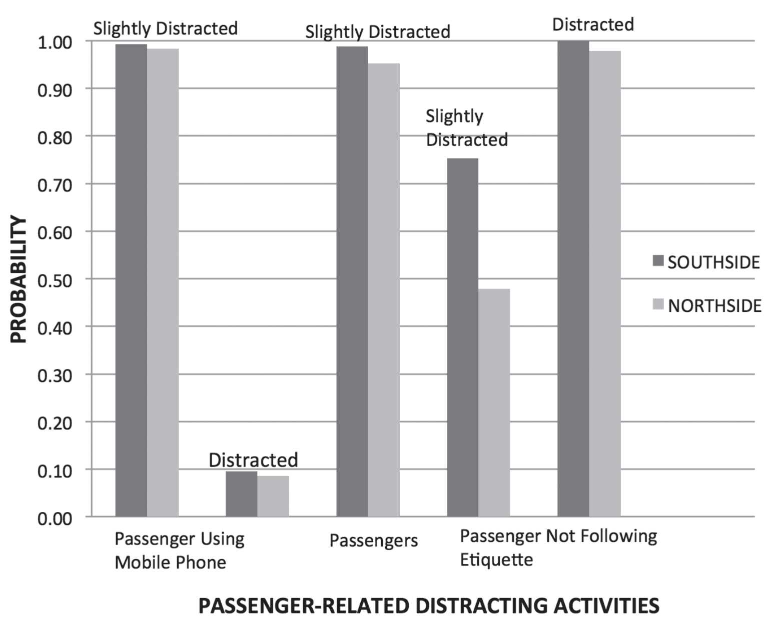


Figure 2. Simulation Results for Location

Gender

The MLR model results indicate that male drivers have a higher likelihood of getting Distracted, followed by Slightly Distracted. The simulation output (Figure 3) validates these results for all the passenger-related activities. The probability values for male drivers are higher compared to female drivers.

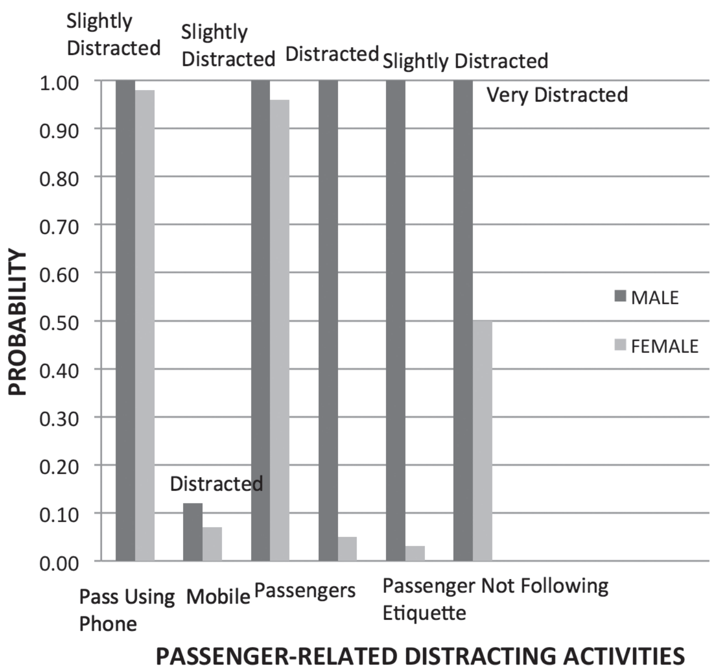


Figure 3. Simulation Results for Gender

Driving Hours/Week

The MLR model results indicate that drivers with more driving hours/week have a higher likelihood of getting Distracted, followed by Very Distracted and Slightly Distracted. The simulation output (Figure 4) for passenger-related activities validates these results with the exception of Passengers Using Mobile Phones (Distracted) and Passenger (Very Distracted).

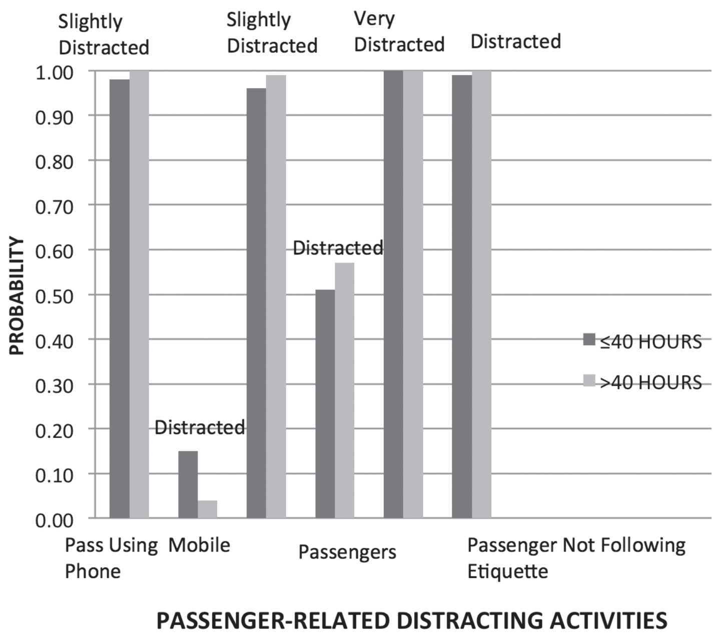


Figure 4. Simulation Results for Driving Hours/Week

Comparison of predicted results generated by the MLR model with simulated outputs for Risk Zones I and II activities show similarities for two-thirds of the model results (D'Souza and Maheshwari 2012a and 2012b). Simulation and predicted results match for certain distraction activities like Passengers Using Mobile Phone and Climate Control for all independent variables namely sex, age, location, experience and driving per week. Two other distraction activities— Passengers Not Following Etiquette and Passengers—match simulation and predicted results for all but one independent variable. However, distraction activity Ticket Machine does not show any convergence between predicted and simulated results for any independent variable. It is possible that survey respondents have confounded between two distraction activities: Ticket Machine and Passengers. In practice, most of the ticket machine distraction can be attributed to passengers. Therefore, those two factors can easily be confounded. Thus, some degree of disagreement between simulation and statistical prediction is possible. A larger sample and better explanation of survey to the respondents should improve result convergence between statistical model and simulation.

Route Observations

Eight route observations covering duration of 15 hours were conducted in the Northside and Southside in winter 2011 and spring 2012 during the late mornings or early afternoon hours are summarized in Table 5. Passengers Using Mobile Phone and Passengers were classified as Risk Zone 1 distracting activities. During the route observations, very few passengers were talking on mobile phones but were not loud enough to be heard by others, including the driver. However, Passengers distraction was observed several times. For example, passengers were observed standing in the "no-go" designated area and the bus driver did not tell them to move back behind the no-standing zone. In certain situations, passengers were standing next to the driver's cab and talking continuously to the driver, causing distractions.

Passengers Trying to Talk to the Driver, Ticket Machine, Fatigue/Sickness, Passengers Not Following Etiquette, Other Road Users, and Pedestrians were classified under Risk Zone II. Talking to the driver was a common distraction but often unavoidable, since less route information was available at the bus station or on the bus compelling passengers to ask the drivers questions. On some routes, passengers talked (personal) continuously with the drivers, causing distraction. Passengers talking briefly with the driver when necessary, for example, during an emergency is permitted by the transit agency, but personal chatting is prohibited. Passengers trying to talk to the driver did not cause visual and physical distractions, but it certainly caused cognitive distraction since it took away the driver's mind from driving. The ticket machine did not appear to cause distractions since it was used by passengers when entering the bus at a stop, except in one instance when a driver was observed operating the ticket machine while pulling away from a bus stop.

The atmosphere in the bus was quiet during non-peak hours but noisy when filled to capacity. On long routes, driver fatigue and restlessness were observed, causing one of the largest apparent distractions for male and female drivers. This is contrary to the results of the MLR model and simulation, which indicated that male drivers get very distracted with fatigue/sickness.

Personal Broadcast (PB) was classified under Risk Zone IV but appeared the most distracting to the drivers. On one route, the driver received three calls/hour on the PB, which took away the attention of the driver from the road. Other distracting activities not included in the study such as unusual sounds emitted from the dashboard, driver seat readjustment, etc., will require further analysis.

Table 5. Summary of Route Observations

Distracting Activity for Zone I And Ii	MLR Model and Simulation Results	Route Observations
Passengers Using Mobile Phones (I)	This distraction was impacted by Location, Gender, Age, Driving Experience, and Driving Hours/Week.	Many passengers were using mobile phones but only a few could be heard at the front by the driver.
Passengers (I)	This distraction was impacted by Location, Gender, Driving Experience, and Driving Hours/Weeks.	Passengers talking to other passengers while standing in the "no-standing zone" next to the driver's cab.
Passengers Talking to Driver (II)	No significant variables.	Passengers were continuously talking to driver mostly asking for information and making personal talk.
Ticket Machine (II)	This distraction was impacted by Location, Gender, Driving Experience, and Driving Hours/Weeks.	Ticket machine was operated during stops and was a distraction when passengers did not have the correct change ready when boarding.
Fatigue/Sickness (II)	This distraction was impacted by Gender of the driver.	Fatigue and restlessness were observed on long routes for male and female drivers.
Passengers Not Following Etiquette (II)	This distraction was impacted by Location, Gender, Age, and Driving Hours/Weeks.	Passengers were noisy when the bus was filled to capacity. Use of profane language was observed during one route.
Other Road Users (II)	This distraction was impacted by Age, Driving Hours/Weeks.	No distraction observed.
Pedestrians (II)	No significant factors.	No distraction observed.
Other Distracting Activities	None	1. High pitch buzzing sound from bus dashboard. 2. Driver was required to write while driving. 3. Driver's back rest required constant adjustments.

Conclusions and Limitations

The results of the MLR models, simulation, and route observations indicate that passenger-related activities classified under Zones I and II are most distracting to the driver. The results of the MLR model and simulation do show that passengers using mobile phones caused the highest distraction, which contradicts the route observations. The insufficient number of route observations conducted mostly during the non-peak hours did not identify this distraction. Also, the cognitive type of distraction caused by passengers using mobile phones is more challenging to detect by the route observer. A larger sample of route observations during peak hours (early morning and late afternoon) could possibly detect this distraction.

Mobile phone usage in public transit systems is an annoyance and distraction to other passengers and the driver. To avoid such situations, a growing number of cities and states have banned the use of mobile phones in the transit system. Although PB appeared to be distracting to the route observer, it was classified in Risk Zone IV (Low Risk). The drivers did not perceive PB to be distracting since it is considered a part of the driving tasks. Also, the route observers' understanding of distraction may differ from the driver's understanding, especially for cognitive distractions.

It is a challenge for a transit agency to develop effective policies for handling passenger behavior so that they are less likely to stand next to the driver's cab, talk to the driver, engage in using cell phones, non-etiquette, and noisy behavior etc. Providing route maps in the bus and at the stops would reduce talk between passenger and driver. Personal use of electronic devices could be allowed beyond the middle section of the bus to avoid distracting the driver. The front section of the bus could be designated as "cell phone free," not enforceable through legislation but by posting friendly sign boards. Drivers must not permit passengers to stand next to the driver's cab to avoid unnecessary communications with passengers, and appropriate sign boards need to be posted in the bus. If conversation cannot be avoided, it must be done cautiously while driving or when the bus is stopped.

The design of ticket machines, control panels, and other devices must be user-friendly and not require long glances away from the roadway. An educational training program on the proper use of technological devices mounted in the cab or issued to the driver and hazards associated with using these devices while driving should focus on drivers who are likely to be distracted by these devices.

How could the transit agency use the MLR models developed in this study? They could be applied to predict distraction for varying driver demographic backgrounds and driving patterns. It is observed that drivers are affected differently by distracting activities, which possibly could be corrected through proper training. Transit agencies could develop driver-based MLR models for each risk zone activity from its existing driver database. These models could be used for predicting the probability of a new driver getting distracted by high-risk activities. If the probability is high, the new driver could be scheduled for related training. Furthermore, other transit agencies could use this study as a framework for conducting similar distraction analysis of their drivers (D'Souza et al. 2012).

The sample size of 48 drivers amounts to a 9.6:1 ratio for the number of cases to independent variables, which is near the minimum case-to-variable ratio of 10:1 but below the preferred case-to-variable ratio of 20:1 favored by researchers (Petrucci 2009). The literature has not recommended any specific approach for computing the sample size. In addition to the five independent variables, other variables such as environmental, vehicle, roadway designs, etc., which could also have an impact on driver distraction (Washington et al. 2011; Morfoulaki et al. 2007; Yan et al. 2009; Gkritza et al. 2006), need to be included in the MLR model.

The presence of multicollinearity that was detected from the Pearson correlation analysis makes it difficult to determine the relative importance of each independent variable on the MLR model and the effects on the dependent variable (Washington et al. 2011). The increase in sample size may reduce the standard error, thereby mitigating the threat of multicollinearity. Furthermore, due to the exploratory nature of the study and the small sample size, the MLR data were not tested to show that they meet the Independence of Irrelevant Alternative (IIA) specifications, which require the ratio of probabilities of selecting any two alternatives to be independent of the third choice (Small and Hsiao 1985). This test is planned for future studies covering larger samples of bus drivers.

This paper is one of only a few to include the full range of distractions and associated risks in public transit buses. The results support the hypothesis that the likelihood of driver distraction is related to his/her demographics, driving hours/week, and location in two-thirds of cases. But it has limited applications due to the localized sample size and limitations discussed above; hence, discrepancies need to be followed up with fresh inputs from an expanded study covering a larger sample of drivers from other agencies. The expanded data set, thus, can be used for validation as well as further refinement of the proposed models. Knowing the activities that cause a high risk of distraction as well as the responsible factors may provide additional input to law and policy makers while crafting legislation and regulations statewide or nationwide.

References

D'Souza, K. A, S. K. Maheshwari, and Z. Banaszak. 2012. Research framework for studying driver distraction on Polish city highways. To appear in *Journal of*

Foundations of Management, Faculty of Management, Warsaw University of Technology, Warsaw, Poland.

D'Souza, K. A., and S. K. Maheshwari. 2012a. Improving performance of public transit buses by minimizing driver distraction. *Proceedings of the Urban Transport 2012 Conference*, A Coruňa, Spain, May 13-16, 2012. Editors: J.W.S. Longhurst and C.A. Brebbia. Wessex Institute of Technology Press, Southhampton, U. K: 281–293.

D'Souza, K. A., and S. K. Maheshwari. 2012b. An analysis of transit bus driver distraction using multinomial logistic regression models. *On-line Proceedings of the Journal of the Transportation Research Forum*, Tampa, FL, March 15–17. www.trforum.org/forum/2012.

Field, A. 2009. Logistic regression. In *Discovering Statistics Using SPSS*, 3rd Edition. SAGE Publications Ltd.: 264–315.

Gkritza, K., D. Niemeier, and F. Mannering. 2006. Airport security screening and changing passenger satisfaction: An exploratory assessment. *Journal of Air Transport Management* 12: 213–219.

Morfoulaki, M., Y. Tyrinopoulos, and G. Aifadopoulou. 2007. Estimation of satisfied customers in public transport systems: A new methodological approach. *Journal of the Transportation Research Forum* 46 (1): 63–72.

Moutinho, L., and G. Hutcheson. 2011. Multinomial logistic regression. In *The SAGE Dictionary of Quantitative Management Research*. SAGE Publications Ltd.: 208–212.

Peng, C. Y., and R. N. Nichols. 2003. Using multinomial logistic models to predict adolescent behavioral risk. *Journal of Modern Applied Statistical Methods* 2(1): 1–13.

Petrucci, Carrie J. 2009. A primer for social worker researchers on how to conduct a multinomial logistic regression. *Journal of Social Service Research* 35(2): 193–205.

Salmon, P. M., K. L. Young, and M. A. Regan. 2011. Distraction "on the buses": A novel framework of ergonomics methods for identifying sources and effects of bus driver distraction. *Applied Ergonomics* 42: 602–610.

Salmon, P. M., K. L. Young, and M. A. Regan. 2006. Bus driver distraction stage 1: Analysis of risk for State Transit Authority New South Wales bus drivers. Final Report. Monash University Accident Research Center, Victoria, Australia.

Small, K. A. and C. Hsiao. 1985. Multinomial logit specification tests. *International Economic Review* 26(3): 619–627.

Smith, D. I., J. Chang, D. Cohen, J. Foley, and R. Glassco. 2005. A simulation approach for evaluating the relative safety impact of driver distraction during secondary tasks. 12th World Congress on ITS, San Francisco, November 6–10, Paper 4340.

SPSS 17.0. 2008. SPSS Inc., Chicago, IL.

U. S. Department of Transportation. 2009. An examination of driver distraction as recorded in NHSTA Databases. DOT HS 811 216.

U. S. Department of Transportation. 2010. Statistics and facts about distracted driving. www.distraction.gov/stats-and-facts.

Washington, S. P., M. G. Karlaftis, and F. L. Mannering. 2011. Logistic regression, discrete outcome models and ordered probability models. In *Statistical and Econometric Methods for Transportation Data Analysis*. Chapman & Hall/CRC: 303–359.

Yan, X., E. Radwan, and K. K. Mannila. 2009. Analysis of Truck-Involved Rear-End Crashes Using Multinomial Logistic Regression. *Advances in Transportation Studies an International Journal* Section A 17: 39 – 52.

Yang, C. Y. D. 2007. Trends in Transit Bus Accidents and Promising Collision Countermeasures. *Journal of Public Transportation* 10 (3): 119 – 136.

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Development and Application of a Rural Intercity Demand Model

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Abstract

This paper describes the development of a demand model to estimate ridership for rural intercity bus services in the United States. The need for such a model and the approach used in developing it are described. Two models were developed, one a regression equation calibrated on data from a survey of rural intercity services, and the other using a trip rate developed from National Household Travel Survey data. Both models are included in a toolkit that also includes user information and population data. The paper then compares the ridership predictions made using the model with actual experience on rural intercity routes in Washington State and illustrates how it can be used as part of a statewide assessment for Vermont. Conclusions about its applicability and directions for future research are presented.

Background

The national intercity bus network has been contracting in coverage for many years, but a substantial shift away from services in rural areas began with the passage of the Bus Regulatory Reform Act in 1982. Following the loss of substantial amounts of rural intercity bus service subsequent to regulatory reform, the Intermodal Surface Transportation Efficiency Act (ISTEA), passed by Congress in 1991, created the Section 18(i) program of assistance for rural intercity services, offering operating, capital, and administrative funding to the states for use in maintaining or developing rural intercity services. This program was subsequently codified as

Section 5311(f). SAFETEA-LU (Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users) continued the program and added a requirement that the states consult with stakeholders (including intercity bus operators) when deciding whether or not to use the funding for intercity bus (as opposed to other rural) needs. The most recent transportation authorizing legislation, MAP-21, included statutory language supporting the in-kind match.

It should be noted that this program, and the demand model described here, relate to rural intercity bus services but not to the expanding express services. In recent years, a major expansion of intercity bus services has taken place as "curbside" express bus services have provided increased frequencies of non-stop (or limited stop) services. Initially beginning with express services linking the "Chinatown" areas of major cities in the northeast, this type of service offers Internet reservations, discount fares, curbside pickup and dropoff, and express service with few, if any, intermediate stops. This bus service model has now been developed and expanded by major carriers. Greyhound Lines joined with Peter Pan Bus Lines to create BoltBus services between major cities in the northeast (and now between Seattle and Portland). Coach USA, a subsidiary of Stagecoach of the United Kingdom, imported its Megabus service model from the United Kingdom. These services operate out of a number of hubs in the northeast, southeast, midwest and now Texas. Greyhound is now providing a similar service on many city pairs, branded Greyhound Express. However, to this point, these services have benefited large cities or major college towns, and the expansion of frequency has had little impact on small towns in rural areas (unless home to a major university).[1]

The availability of this funding and the existence of State-funded programs in several states calls for a tool to identify which potential rural intercity feeder markets make sense based on the projected ridership and revenue. State and regional planners, bus companies, and rural transit operators need a demand model, rule of thumb, or similar tool that is based on recent experiences to assist in determining the likely intercity-related ridership and the impact of different arrangements on the potential demand. Most basically, a way to estimate intercity trip demand from rural areas to larger cities is needed to help in the design of projects that will link rural areas with major urban areas and the national intercity network. The level of demand obviously varies with population, and probably with frequency and service design, and is a major consideration in service design issues.

The need for such a tool led to a Transit Cooperative Research Program (TCRP) project to create a rural intercity demand model. The results of that effort are now available in TCRP Report 147, "Toolkit for Estimating Demand for Rural Intercity Services."[2] This paper provides an overview of the results of the research effort, the toolkit developed to facilitate user application of the results, and finally it presents examples illustrating the application of the model and toolkit to estimate demand for rural intercity services in Washington State and Vermont. This paper is intended to inform the reader about the existence of this research, and also to present some additional information about the results of its application.

Purpose of the Project

The objective of this research project was to develop a sketch planning guide and supporting tools that could be used by state transportation department program managers and public and private rural intercity bus service providers to forecast demand for rural intercity bus services.

The potential audience for this research includes state agency program officials and staff, planners, local officials, existing and potential public and private operators, and sponsors of rural intercity bus service.

Review of Previous Demand Estimation Methods

TCRP Report 147 documents a number of approaches to the estimation of rural intercity bus demand.[3] During the 1980s, as the bus industry restructured following deregulation, the interest in potential state or federal programs to provide operating or capital assistance led to a number of efforts to develop demand models. More recent efforts at planning have used earlier models or other sketch-planning techniques to estimate potential ridership. The approaches used in the various studies have varied according to the desired application and the available data. Approaches have included the use of:

- Per capita intercity trip generation rates
- Ridership on comparable services
- Historical data
- Stop-level regression models
- Route-level regression models
- City-pair regression models, and
- Network models

Several applications of these approaches are documented in the TCRP report, including the use of trip rates in the Washington intercity bus plan and the use of a regression model to estimate demand and revenue for a Virginia study.

Inventory of Existing Rural Intercity Routes and Ridership

An important and significant part of the effort to develop a demand model for rural intercity bus ridership involved an effort to identify current or recent rural intercity bus services, their characteristics, and their ridership. These basic data elements are critical to the ability to calibrate or evaluate any type of technique for estimating ridership. Chapter 3 of TCRP Report 147 describes the type of data sought and the survey methodology to collect the data.

Initially, all the service characteristics that could potentially affect ridership were identified as was the list used to develop a survey for completion by the agency or firm operating the service. Initial pilot tests of the survey resulted in a shortened version.

A second step involved the identification of rural intercity services. Because it was anticipated that the resulting models would be used primarily to estimate ridership on services funded with Section 5311(f) operating assistance, the approach taken involved contacting the transit programs in all state departments of transportation to determine if they had provided operating funding for rural intercity bus service in the past three years. If so, we requested contact information for the provider and also any information available at the state level on service characteristics or ridership. Additional effort went into using other data sources such as websites and industry schedule guides to develop service characteristics. The effort involved in identifying the state contacts, contacting carriers, and obtaining service and ridership data was significant.

The result was a database of routes, with data on the operator, route endpoints, stops, route length, frequency, fare (and/or fare per mile), corridor population, destination population, and presence of potential key generators (college or university, major medical center, airport, etc.). A total of 133 routes were identified, with annual ridership data available for all but 18.

Rural Intercity Bus Classification Scheme

With the database of routes and route characteristics in hand, the study team developed a classification of the services in an effort to combine services with similar characteristics into separate classes. This was done to identify potential commonalities that could assist in the development of demand estimation techniques, or to facilitate the development of separate demand tools for different types of services. An initial classification was developed based on the type of provider. Three classes were developed:

- Services that are comparable to traditional intercity bus services
- Services that are regional in character, provided by private firms
- Services that are regional but operated by public transit providers

For each class, the characteristics of that class were identified based on the data from the survey. Following the efforts to define these classifications more fully to focus on connectivity to the national intercity bus network as a key element of the definition of intercity service, additional data were needed on many of the services to determine if a passenger could use the service (included in the database) to access the national intercity bus network. The revised classification included 99 routes, all considered "rural intercity" for the purposes of this study.

Development of a Sketch-Planning Tool

The process of developing demand estimation tools, even with a fairly large data set, proved to be more problematic than originally thought. Initially, the research team considered all desired characteristics of a model or toolkit. This helped to set the goals for the effort but also made it apparent how difficult it might be to address all potential issues that might be faced by a user. This project was intended only to develop a demand estimation tool or process, not to develop a full planning process.

Two basic development approaches were undertaken. One involved the effort to develop trip rates for the routes and corridors included in the database, potentially including route length as a factor to adjust trip rates. However, when no discernible pattern of trip rates could be developed, several issues were identified. One was the impact of intermediate stops on route-level ridership, and the other was the difficulty in determining the appropriate corridor population to calculate a trip rate when a large metropolitan area is part of the corridor. In such cases, a trip rate that includes the large population will be very different from a route with only rural stops. Eventually, it was decided to determine if trip rates from a separate source could be used to develop a tool that would have predictive value. A special run of the National Household Travel Survey (NHTS) focusing on the long-distance trips made by persons in non-urbanized areas was requested. The resulting data were also classified by income and region. Information on mode share from several sources was used to develop trip rates; the one percent mode share produced ridership estimates most similar to the survey data, and it was chosen for use in the trip rate model or tool.

The alternative approach taken was an effort to develop a multiple regression model using the database. Initial efforts produced models with limited explanatory power. Evaluation of these initial results led to a disaggregation of the population data variable, which was corridor population, into urbanized and non-urbanized components. Finally, improved results came from using populations for Urbanized Areas (over 50,000 population), Urban Clusters (2,500 to 50,000 persons), and Census Designated Places (under 2,500 persons). These provide populations that are not necessarily limited to municipal boundaries.

Analysis of residuals led to continued work with the regression model, this time reducing the cases to eliminate routes that were outliers. A separate variable for the number of stops was also included in the data set. With the elimination of outliers, the data set was reduced to 58 usable cases, and the distinction between standard intercity bus service and regional rural intercity bus service classes was made into a categorical variable.

Continued work with stepwise regression eventually resulted in the best fitting model:

Ridership = -2803.536 + 0.194 (Average Origin Population) +
314.734 (the number of stops on the route) +
4971.668 (airport service or connection) +
5783.653 (service provided by intercity provider)
R^2 = 0.712, Adjusted R^2 = 0.690[4]

Where,

Ridership = annual one-way passenger boardings

Average origin population = sum of the populations of origin points (all points on the route except that with the largest population)

Number of stops = count of points listed in public timetables as stops

Airport service or connection = route serves an airport with commercial service either directly or with one transfer at a common location

Intercity provider = service operated by a carrier meeting the definition of an intercity bus carrier.[5]

A subsequent effort used the residuals[6] from the regression model to adjust the trip rate model results, improving the results slightly over the pure trip rate model, as shown in Table 1:

Table 1. Accuracy of Trip Rate and Regression Models

	1% Trip Rate Prediction	Adj. 1% Trip Rate Prediction	Regression Prediction
Within 50% of actual ridership	45.60%	54.40%	59.60%
Within 10% of actual ridership	14.00%	15.80%	17.50%
Within 5% of actual ridership	8.80%	5.30%	5.30%

Both of these techniques are more accurate for current rural intercity bus services than the demand models estimated for NCHRP in 1980.[7] They represent a pragmatic approach that makes use of available data to produce initial estimates of potential ridership for new rural services. The regression model has the correct signs (e.g., ridership increases with a higher population base, etc.), and is plausible given general knowledge about travel behavior. It reflects higher ridership for intermodal connectivity to airports and for interlining. It uses population data as a key variable, but the impact of population is moderated by using the number of stops to calculate an average population per stop. This is plausible in that we expect ridership to be lower if the bus stops often to serve that population, which seems to reflect market preference for fewer stops.

The use of the NHTS trip rate data also involves making maximum use of the available data. It provides ridership estimates based entirely on population served, but it is calibrated, in a sense, through the selection of the mode choice factor to provide ridership estimates that most closely match the usage found in the data set. Regional variation is introduced through the use of regional trip rates. Finally, the 58-route data set was used to develop an adjustment factor that can be applied to the trip rate model results to further improve its results. The result is that the trip rate model and the regression model have comparable accuracy in terms of the percentage of time they will predict a ridership figure that is within a given percentage of the actual. However, they may not give the same answer.

Both the difficulties experienced and the results suggest that over the past 30 years, rural intercity bus service has become much more specialized, with the remaining routes or services much more likely to be provided in areas with fairly unique demand characteristics. Neither model takes account of the overhead traffic (ridership originating in or destined to places beyond the endpoints of the particular route in question) that might result in ridership variance or other variables such as the presence of a large university or military base that might affect demand.

Toolkit

The major product of this project was intended to be an easy-to-use toolkit to assist planners in estimating ridership on rural intercity routes. It was decided that the tools would best be provided on a CD with the models and their calculations embedded so that users would not have to deal with formulas or look up tables but would merely need to input data for a proposed route to get the model estimates. Users desiring more information about the models and the data can refer to the technical report. The toolkit is, thus, a disk, and it provides the user with a discussion of its applicability, an overview of the elements included, a step-by-step process for estimating ridership (which includes preliminary aspects that would precede use of the models and the information that will be needed from the user), possible manual adjustments to improve accuracy, a detailed example of its application to a case, and a lookup database that provides ridership on comparable routes and a link to more descriptive data about the comparable routes.

Comparison of Model Results to Experience— "Travel Washington"

To illustrate the likely results if a state or regional planner uses the toolkit to estimate the demand for a rural intercity route, the final toolkit was used to estimate ridership on the four rural intercity routes funded by the Washington State Department of Transportation (WSDOT) under its Section 5311(f) rural intercity bus program. WSDOT has branded these services as "Travel Washington" statewide, with each corridor benefiting from a unique regional identity tied to local products. All four corridors connect with the national intercity bus network and offer interline ticketing. At the destination end, the routes also provide stops at Amtrak stations, local transit hubs, and, in one case, a major airport.

For each route, the toolkit CD was used following the accompanying directions. The population data for the corridor came from the CD, and the one-way route length for each route was obtained by using an Internet mapping program to plot the route with the stops as depicted on the WSDOT website. The only other data required are information about whether the route served an airport with commercial service and whether or not the route was operated by a national intercity bus carrier.

Table 2 presents the estimated ridership for each corridor, along with actual ridership. Note that each route has been operating for a different length of time. Overall, the obvious conclusion is that the regression model produces estimates that are much closer to the actual ridership than the trip rate results and that the regression estimates are reasonable for use in planning such services. Further investigation revealed that the high ridership on the Dungeness Line is largely due to the fact that visitors from Canada can access this route from the ferry and use it for service to Seattle, particularly the airport, which has extensive service. Also, the relatively high ridership on the Grape Line in part reflects continued growth; the ridership in the initial two years was closer to the regression estimate. It should be noted that the model does not necessarily represent the ridership at any particular time point following the initiation of service. The database used for calibration included routes that were continuations of existing intercity services, new routes, and routes that have been operating for several years. For that reason, the user might exercise caution in creating expectations that the forecast ridership would be achieved in an initial year or even two. However, the continued Grape Line ridership growth beyond forecast demand suggests that the estimate is not necessarily the ultimate limit on what may be achieved.

Planning Application—Potential Rural Intercity Routes for Vermont

A second illustration of potential use of the models can be found in recent work for the Vermont Agency of Transportation. Part of the update of its Public Transit Policy Plan analysis of transit needs found that the loss of rural intercity bus services had left many towns in the state with no direct intercity bus access to major out-of-state travel destinations. In some cases, regional rural public transit services developed primarily to meet commuter needs can be used to make trips within the state or to cities that continue to have intercity bus services. The loss has been dra-

Table 2. Travel Washington Routes: Actual and Estimated Demand

Route Name	Endpoints	Intercity Network Connections	Route Length (Miles One-Way)	Frequency	Incremental Population Served[1]	Start Date[2]	Annual Ridership[3]	Predicted Ridership[4]	
								Regression	Trip Rate
Apple Line	Omak – Wenatchee –Ellensburg	Northwest Trailways and Amtrak in Wenatchee, Greyhound in Ellensburg	49	One daily round-trip	14,708	10/28/08	5,755	5,300	800
Dungeness Line	Port Angeles –Seattle	Greyhound in Seattle, Amtrak in Seattle, Sea-Tac International Airport	98	Two daily round-trips	38,241	9/17/08	14,037	5,900	400
Gold Line	Kettle Falls –Spokane	Greyhound and Northwestern Trailways in Spokane, Amtrak in Spokane, Spokane International Airport	80	Two daily round-trips	11,799	Sept. 2010	3,630 (estimated from first 6 months of 2011)	4,300	500
Grape Line	Walla Walla –Pasco	Greyhound and Amtrak in Pasco, Tri-Cities Airport	160	Three daily round-trips	43,959	12/10/07	8,824	6,300	2,600

[1] *Combined population of urbanized areas and urban clusters that are stops on the route, not including the population of points that also receive other intercity bus services. For example, the population of Seattle is not included on the Dungeness Line, because it has other intercity bus services and does not require the Travel Washington program to provide access to the intercity bus network.*

[2] *Date that the line began service under the Travel Washington Intercity Program. Both the Apple Line and the Dungeness Line had previously been in operation under different branding and funding arrangements, and the Grape Line had previously operated for a brief period under a different grantee and funding arrangement.*

[3] *Calendar 2010 ridership, except for the Gold Line as noted.*

[4] *Estimated annual ridership using "TCRP Report 147: Toolkit for Estimating Demand for Rural Intercity Services."*

matic, with 50 places receiving intercity bus service in 1998,[8] declining to 6 places with such service today.

The arrival of Megabus services did not add any small towns to the intercity map, as Megabus serves only the largest city in the state, Burlington, with express services to Boston and New York City. Other intercity services include Greyhound Lines, with five stops, and Yankee Trails, with one stop. Given that there is a concentration of remaining service in Burlington and in the Lebanon-Hanover (New Hampshire)-White River Junction (Vermont) urban cluster, a possible policy change for Vermont would be to use Section 5311(f) rural intercity funding for rural intercity routes from various points in the state to connect to these hubs for onward service to New York, Boston, Montreal, Albany, and other places that are both key regional destinations and connection points for other transportation services. Given a limited budget for such services, the state is interested in determining the likely ridership, potential revenue, and costs for such routes in order to focus limited resources most efficiently. The TCRP 147 rural intercity demand toolkit was used to estimate ridership for a number of corridors, as can be seen in Table 3.

As in the case of Washington, the regression model generally produced higher predictions of ridership, though in cases in which the proposed service would not be provided by a national intercity bus operator and would not serve an airport, low population corridors generally had regression predictions that are lower than the trip rate results. Only one of these corridors is currently in operation, the White River Junction to Springfield, Massachusetts, service operated by Greyhound. No ridership data are available, but based on the revenue per mile data provided by that firm, the estimated regression ridership is likely to be slightly below the actual ridership.

Table 3 illustrates that the toolkit can assist in service design, particularly the choice of operator and decisions about serving airports. The regression model in the toolkit reflects that fact that services provided by a national intercity bus carrier were generally found to have higher ridership, probably because of the fact that such services are fully interlined in terms of ticketing and are included in the schedule information, telephone information, and websites of the carriers. This allows inbound and outbound passengers to know about the service and buy tickets, resulting in a higher ridership base.

Table 3. Predicted Ridership for Vermont Intercity Corridors

Route Description	One-Way Distance (Miles)	Connection To	Serves Airport	Potential Operator	Estimated Ridership	
					Regression Model	Trip Rate Model
White River Junction (VT) - Springfield (MA)	143	New York City (NYC)	No	National Intercity Carrier	8,200	3,800
			No	Non-Intercity Bus Operator	2,400	3,800
Rutland - White River Junction	51	Montreal, Boston, NYC	No	National Intercity Carrier	6,000	2,100
			No	Non-Intercity Bus Operator	200	2,100
Rutland - Burlington	68	Boston, Montreal	Yes	National Intercity Carrier	11,000	2,700
			Yes	Non-Intercity Bus Operator	5,200	2,700
Albany (NY) - Burlington	158	NYC, Montreal	Yes	National Intercity Carrier	14,500	3,700
			Yes	Non-Intercity Bus Operator	8,700	3,700
Brattleboro - Nashua (NH) - Boston (MA)	66	Boston	Yes	National Intercity Carrier	18,100	18,000
Brattleboro - Nashua (NH)	66		No	National Intercity Carrier	6,900	800
	66		No	Non-Intercity Bus Operator	1,100	800
Brattleboro - Springfield (MA)	59	NYC, Albany	Yes	National Intercity Carrier	12,700	4,800
			Yes	Non-Intercity Bus Operator	6,900	4,800
St. Johnsbury - White River Junction	60	Boston, NYC	No	National Intercity Carrier	4,600	600
			No	Non-Intercity Bus Operator	0	600
Newport - White River Junction	102	Boston, NYC	No	National Intercity Carrier	5,900	2,400
			No	Non-Intercity Bus Operator	100	2,400
St. Albans - Burlington	29	Boston, NYC	Yes	National Intercity Carrier	10,500	1,700
			Yes	Non-Intercity Bus Operator	4,700	1,700
Albany (NY) - Brattleboro - Manchester (NH)	164	NYC, Boston	Yes	National Intercity Carrier	24,700	13,640
			No	Non-Intercity Bus Operator	100	2,400
Albany (NY) - Rutland - White River Junction	139	NYC, Boston	No	National Intercity Carrier	7,300	3,100
			No	Non-Intercity Bus Operator	100	2,400

The demand estimates developed using the model are potentially most useful not just by themselves, but as part of an overall comparison of potential routes or route segments in terms of cost-effectiveness. However, the demand estimate is just one element of such an overall planning process. Once a ridership estimate has been developed, it is necessary to convert the ridership into an estimate of revenue. Typically, planning efforts have done this in the past by multiplying the ridership times an estimated average (national) intercity bus fare per trip. Alternatively, it would require estimating the average trip length for the passenger to estimate passenger-miles and then multiplying that figure times a revenue-per-passenger-mile figure.

The other element of using ridership as part of an overall comparison of cost-effectiveness is the estimation of costs to operate the route or service in question. Costs are likely to differ among types of firms, with national carriers having higher costs than local or regional firms and potential differences between public and private carriers. The source for recent data on projected revenue per trip or per passenger-mile and carrier operating costs is likely to come from the Federal Transit Administration (FTA)-required consultation process or from recent carrier grant applications.

To planners developing services, the higher potential ridership for a national carrier (as predicted by the model) is one reason to prefer a national carrier; at the same time, the higher operating costs of such firms may offset that advantage. For longer routes with high ridership, contracting with a firm that is part of the national intercity bus network may be necessary to provide peak capacity, but for shorter routes the optimal solution may involve contracting with local carriers or public transit providers that have lower operating costs but requiring them to be fully interlined with national networks to maximize ridership to and from the national network. If the ridership benefit from being part of the national network can be combined with lower costs, operating assistance requirements can be minimized.

Similarly, the potential additional ridership that could result from serving an airport can be compared to the potential additional costs of such service in terms of time and miles (and airport access costs).

Finally, the toolkit can be used to evaluate particular situations that may affect potential ridership. For example, in the Burlington-Albany corridor, the predicted ridership is 14,500 using the regression model. However, Megabus now operates express services from Burlington to New York City with a stop just north of Albany. These services may have taken all the passengers from that route who are destined for New York. The impact of such a scenario can be tested by eliminating Burlington from the model inputs. The model procedure already eliminates the population of the "destination" city, Albany, as it is the city with the largest population on the route. It is removed to reflect the fact that it likely already has substantial intercity service. To adjust the model result to reflect the potential impact of the Megabus service, the user can also drop Burlington so that the predicted ridership reflects only the intermediate towns. In that case, the predicted regression ridership falls to 11,700.

Conclusions and Directions for Further Research

The toolkit models provide a tool that can be used as part of an overall planning process to evaluate potential routes. The two methods produce different results that can be used to create conservative scenarios for funding decisions and to test the impact of alternative service providers and airport service. The results are based on national data and provide order-of-magnitude predictions.

The two models developed in this process are limited in that they are not sensitive to changes in fares or frequency and that they do not account for ridership that might arise from population not directly served by the route—for example, through passengers who use the service because it bridges two other routes or riders coming from other modes or going to places with no population (parks, for example). The trip rate model relies on data from the previous NHTS, and the population data are from the 2000 Census, so an update needed.

Directions for future research on intercity bus demand could include additional effort to obtain data on more routes, particularly as the Section 5311(f) program expands. Models to predict demand at a stop would also be useful, as would tools that could allow planners to gauge the impacts of higher frequencies or lower fares. The impact of the availability of long-term parking at stops or terminals is another factor that could be considered in future research. Finally, a major step in developing a tool for estimating intercity bus demand generally would be a network model that would allow for the inclusion of overhead ridership, facilitating the estimation of demand for service to fill network gaps as well as serve populations on a route.

However, it should be noted that demand is only one factor in analyzing potential services. Another potentially useful direction for research is the development of the remainder of the rural intercity bus planning process, including techniques and factors to convert estimated ridership into revenue estimates, estimate operating costs, calculate subsidy needs, and provide performance measures to facilitate comparisons among alternatives.

Endnotes

[1] Schwieterman and Fischer, "The Intercity Bus: America's Fastest Growing Transportation Mode, 2010 Update on Scheduled Bus Service," Chaddick Institute for Metropolitan Development, DePaul University December 20, 2010, p. 3.

[2] Fravel, et al., "TCRP Report 147: Toolkit for Estimating Demand for Rural Intercity Bus Services," Transportation Research Board, Washington, D.C., 2011.

[3] Fravel, TCRP Report 147. Chapter 2 discusses the previous demand modeling techniques.

[4] In a regression equation, the term R-squared refers to the fraction of the sample variance of the dependent variable that is explained by the regressors. Adjusted R-squared is a modified version of R-squared that does not necessarily increase when a new regressor is added to that regression. In general, a higher value of R-squared means that the model has more explanatory power. See pp. 193-195 in Stock and Watson, Introduction to Econometrics, 3rd Edition, 2010.

[5] As defined on the Toolkit CD, these are rural intercity routes provided in the traditional intercity model, generally with low frequencies (one daily round-trip or less), comparable distance-based fares ($0.10 to $0.17 per passenger-mile), interline ticketing (through the National Bus Traffic Association), information about connections through national bus information systems (Russell's Guide, Greyhound telephone/on-line information, etc.), generally operated by private for-profit firms.

[6] Stock and Watson, pp. 190-191.

[7] Burkhardt and Riese, "Estimating Travel Demands for Intercity Bus Routes," presented at the Transportation Research Board 61st Annual Meeting, Washington, D.C., January 1982.

[8] KFH Group, Inc., "Vermont Statewide Intercity Bus Study," prepared for the Vermont Agency of Transportation, 1998, p. 2-1.

References

Burkhardt, Jon E., and Jeffrey I. Riese. 1982. Estimating travel demands for intercity bus routes. Presented at the Transportation Research Board 61st Annual Meeting, Washington, D.C., January.

Fravel, Frederic D., Reyes Barboza, Jason Quan, and Jason Sartori. 2011. TCRP report 147: Toolkit for estimating demand for rural intercity bus services. Transportation Research Board, Washington, D.C.

KFH Group, Inc. 1998. Vermont statewide intercity bus study. Prepared for the Vermont Agency of Transportation: 2-1.

Schwieterman, Joseph, and Lauren Fischer. 2010. The intercity bus: America's fastest growing transportation mode, 2010 update on scheduled bus service. Chaddick Institute for Metropolitan Development, DePaul University, December 20: 3.

Stock, James H., and Mark W. Watson. 2010. *Introduction to Econometrics*, 3rd Edition. Boston: Pearson Education.

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Use of Alternative Fuels and Hybrids by Small Urban and Rural Transit

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Abstract

To better understand the problems and benefits of using biodiesel, E85, propane, natural gas, and hybrid vehicles in smaller communities, a survey of 115 small urban and rural transit agencies was conducted. This study describes the use of alternative fuels and hybrids by these transit providers; identifies motivating factors and deterrents for adoption; describes the experience of transit agencies that have adopted these alternatives, including costs, maintenance, reliability, and overall satisfaction; and examines differences between those agencies that use these alternatives and those that do not, as well as differences between rural and small urban areas. Larger agencies and those operating in urban areas were found to be more likely to adopt alternatives than smaller, rural providers. Beliefs about the benefits of emissions reductions, improved public perception, and cost savings were the greatest motivating factors for adoption, and concerns about infrastructure costs and fuel supply were the most likely to negatively influence adoption.

Introduction

Transit agencies of all sizes across the U.S. have been or are considering using hybrid-electric vehicles or alternative fuels such as biodiesel, compressed natural gas (CNG), propane, or E85. The use of these alternatives has increased in recent years due to concerns about environmental and energy issues and increased incentives and regulations from local, state, and federal governments that have encouraged their use. Benefits to transit agencies for using alternative fuels and hybrids have been documented in terms of reduced emissions of harmful pollutants, such as carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), and hydrocarbons (HC) (FTA 2006; FTA 2007; Nylund et al. 2004). A reduction in life-cycle greenhouse gas (GHG) emissions has also been found (FTA 2007; EPA 2007; Beer et al. 2002). On the other hand, a number of barriers have prevented widespread adoption, including higher capital costs of vehicles and supporting facilities, reliability concerns, and limited availability of alternative fuels (FTA 2006).

Transit agencies have been leaders in using alternative fuel vehicles. Smaller transit agencies, including those operating in small urban and rural areas, however, may face greater difficulties in making the transition. Infrastructure or capital costs could be prohibitively expensive, or the agencies could lack the resources and expertise to successfully operate these vehicles. Furthermore, the supply of vehicles designed to meet their standards could be limited, as could an adequate and dependable supply of the fuel. Reliability and maintenance issues could also be a concern for smaller agencies that could face significant disruptions in service if any of their vehicles were out of service.

Small urban and rural transit agencies need to be fully informed of the costs and benefits of alternative fuels and hybrid vehicles before adoption, and they can learn from the experiences of those that have been using these alternatives. Decision makers also need to understand the needs and concerns of transit agencies. While previous research has identified advantages and disadvantages from using alternative fuels and hybrid buses, less is known about the factors that motivate agencies to adopt these alternatives or the degree to which different deterrents are preventing adoption, especially among small urban and rural transit agencies.

A survey was conducted of small urban and rural transit agencies to learn more about these motivating factors and the experiences of transit systems. The survey focused on biodiesel, E85, propane, natural gas, and hybrid-electric vehicles. It asked users to identify their motivations for adoption, concerns before adoption, overall satisfaction, and problems experienced. Non-users were asked to identify deterrents to adoption and potential benefits from adoption. A logit model was estimated to determine the impacts of agency characteristics and beliefs about benefits and deterrents on the likelihood of adopting biodiesel or hybrid vehicles. An ordered logit model was also estimated to determine the characteristics of agencies more likely to have successful experiences with biodiesel. The findings provide useful information to policy makers and transit operators considering adoption.

Survey Design, Administration, and Response

The survey was targeted toward transit providers in small urban or rural areas. Small urban providers were defined as those receiving Section 5307 funding and operating in areas with a population below 200,000, and rural providers were defined as those receiving Section 5311 funding. A list of small urban transit agencies was obtained from the 2008 National Transit Database (NTD). Using the NTD, 394 small urban transit systems were identified. Contact names and email addresses were found for 305 of these transit agencies.

The survey was also targeted to 270 rural transit agencies, which represented the largest 20 percent of section 5311 providers measured in terms of vehicle miles of service as reported in the 2009 rural NTD. The survey was limited to the larger rural systems, since many of the smaller rural operators may not be considering alternative fuels and hybrids, and there was a concern about getting a poor response rate from these agencies, as well as significant self-selection bias. Contact information, which was developed previously for a survey by Ripplinger and Brandt-Sargent (2010), was available for 245 of these 270 agencies. Combined, the survey was sent to 550 transit providers.

The survey was administered online. E-mail invitations were sent to transit agencies with a link to the survey. The original e-mail invitation was sent on March 29, 2011, and a reminder e-mail was sent eight days later. The survey was kept open until the end of April. Of the 550 e-mail invitations sent, 56 were returned undeliverable, possibly due to outdated contact information, which left 494 transit agencies that received the survey. A total of 115 responses were received, yielding a response rate of 23 percent. The full survey and complete results can be found in Mattson (2012).

Agency Characteristics

Survey results were received from transit agencies in 36 states. Fifty-four of the responding agencies were from small urban areas, and 37 were rural transit operators (the remaining respondents did not identify their location). Additional data from the NTD were used to identify characteristics of responding agencies for those that provided their location or name of agency. These agencies provided an average of 1.1 million vehicle revenue miles, 64,000 vehicle revenue hours, and

913,000 trips in 2009. Median values for these agencies were 733,000 vehicle miles, 45,000 vehicle hours, and 367,000 trips.

For the small urban systems, about two-thirds of the vehicle miles provided was for fixed-route service, while about one-third of vehicle miles for the rural systems was for fixed-route service. The small urban systems provided an average of 1.29 trips per mile while traveling 13.7 miles per hour, compared to rural systems that provided an average of 0.25 trips per mile at 28.0 miles per hour. The rural agencies tend to travel at higher speeds and travel more miles per trip. These differences may influence an agency's decision to use an alternative fuel or hybrid vehicle.

Biodiesel is the most commonly-used alternative fuel among small urban and rural transit operators. Thirty-one of the responding agencies use biodiesel, while 10 use CNG, 8 use E85, 4 use propane, and 24 own hybrid-electric vehicles. Among biodiesel users, about half use a 20% blend at least some of the time, while the remainder uses a lower blend.

Perceived Benefits and Deterrents

Reducing emissions, energy dependency concerns, political directives, improving public perception, and fuel cost savings were common motivating factors for agencies that have adopted alternative fuels or hybrids. Reducing emissions was commonly mentioned as a major reason for adopting hybrids (16 out of 24 respondents) or CNG vehicles (8 out of 10), but it was more often noted as a minor reason for adopting biodiesel. Similarly, a greater percentage of hybrid users mentioned energy dependency concerns (11 of 22) and improving public perception (16 of 23) as a major reason for adoption than did biodiesel users. (Of 21 responding biodiesel users, 6 considered energy dependency concerns a major reason and 5 considered improving public perception a major reason.) Responses regarding energy dependency suggest that public transportation agencies are becoming more sensitive to their role as energy consumers and are seeking ways to help reduce the nation's dependence on fossil fuels and oil imported from other countries.

Fuel cost savings was also a major reason most hybrid users (19 of 24), and half of CNG users adopted those vehicles, while fuel cost savings was not a motivating factor for biodiesel use. Political directives were cited as a major reason for 9 of 22 biodiesel users and 10 of 23 hybrid users.

For agencies that have not used alternative fuels or hybrids, deterrents differed for each alternative. The major findings were as follows:

- Fuel cost was found to most likely be a deterrent for biodiesel (25 of 56 respondents called it a major deterrent).
- Fuel mileage was often considered (33% of non-users) a major deterrent for E85, and some agencies (18%) also considered it a major deterrent for biodiesel.
- One of the most significant deterrents for adopting alternative fuels and hybrids was concern with maintenance issues. This was commonly mentioned as a major deterrent for all alternatives (49% of biodiesel non-users, 29% of E85 non-users, 45% of propane non-users, 47% of CNG non-users, and 45% of hybrid non-users). Some agencies (31%) were also concerned about fuel quality as a major problem for biodiesel.
- Lack of an adequate and dependable fuel supply was a major deterrent for all alternative fuels. This was listed as a major deterrent for about half of E85, propane, and natural gas non-users and two-thirds of biodiesel non-users.
- Lack of information was considered a major deterrent for about one fourth to one third of agencies, regardless of the alternative.
- Overall performance was most likely to be considered a deterrent for hybrid vehicles, as 28 of 66 non-users considered vehicle performance to be a major deterrent.
- Vehicle availability was a major deterrent for 45 percent of agencies for hybrids and 42 percent of agencies for propane vehicles. It was considered less of a deterrent for E85 and was not a deterrent for biodiesel use.
- Vehicle cost was the greatest deterrent for use of hybrids (78% of respondents called it a major deterrent) and also one of the most significant deterrents for propane and natural gas use (64% and 60% of propane and natural gas users, respectively, cited it as a major deterrent).
- Development and implementation of new fuel infrastructure and modifications to maintenance facilities were the greatest deterrents for use of propane and natural gas, as about three-quarters of respondents referred to these as major deterrents. Over half of respondents also considered infrastructure cost as a major deterrent for biodiesel.
- Safety hazards and limited vehicle range were considered major deterrents by a significant number of agencies for adopting propane (38% and 43%, respectively) or natural gas (37%).

Experiences of Alternative Fuel and Hybrid Users

The experiences of agencies that have adopted these alternatives can differ from the expectations or perceptions of non-users. For those agencies that use these alternative fuels or hybrids, fuel cost was most likely to be a problem for biodiesel (32% called it a major problem) or E85. Maintenance issues were more likely to be a major problem for biodiesel (23%). For all alternatives, though, a majority of users experienced no maintenance problems, and many of the problems encountered were minor. The responses regarding reliability were similar, with the greatest problems being for biodiesel (19% called it a major problem). Adequate and dependable fuel supply was most likely to be a problem for E85 (1 of 6 users called it a major problem and 4 cited it as a minor problem). Most of the fuel supply problems for E85 and other fuels were considered minor. Overall, users of alternative fuels and hybrids tend to be satisfied (Table 1).

Table 1. Satisfaction Reported with Each Alternative Fuel and Hybrid

	N	Very Satisfied	Somewhat Satisfied	Neither Satisfied nor Dissatisfied	Somewhat Dissatisfied	Very Dissatisfied
Biodiesel	22	27%	36%	14%	18%	5%
E85	7	29%	0%	57%	14%	0%
Propane	4	0%	75%	25%	0%	0%
CNG	9	56%	44%	0%	0%	0%
Hybrid-electric	24	50%	17%	8%	8%	17%

Cold weather performance is often considered a major deterrent for use of biodiesel, especially in colder climates. A survey of state DOTs by Humberg et al. (2006) found that the most common deterrent for biodiesel adoption, besides cost, was concerns about cold weather performance, but cold weather behavior was not found to be a widespread problem for those state transportation agencies that had adopted the fuel. Our study found similar results. Among the responding agencies that use biodiesel, 48 percent considered cold weather performance to be a major concern before adoption, but just 23 percent have considered it a major problem since adoption. Still, it is an issue to contend with. Most transit providers in northern states switch to a lower blend in the winter.

Transit agencies most satisfied with E85 use the fuel more often. For example, of the three that use E85 more than 90 percent of the time, two were very satisfied with it. The most satisfied CNG users have been using the fuel longer, more than 10 years.

Overall, most hybrid users have not experienced problems greater than what they have experienced with conventional vehicles, with some exceptions. Many plan to purchase additional hybrids within the next five years. The most significant concerns were the additional vehicle costs and whether users in rural areas would ever achieve any savings.

In many cases, agencies were more likely to view an issue as being problematic before adoption than to actually experience the problem afterwards. This is especially observed for biodiesel users regarding maintenance issues, cold weather performance, and fuel quality. Fuel cost was the one issue biodiesel users were more likely to find problematic than they expected. Four of these agencies using E85 considered adequate and dependable fuel supply as a major deterrent, but only one listed it as a major problem since adoption. Similarly, two E85 users considered maintenance issues as a major concern before adoption, but none said it was a major problem after adoption. Reported problems for hybrid users were also not as great as the concerns reported before adoption.

Regarding fuel economy, 18 of 24 respondents using hybrids have noted an increase in miles per gallon, ranging from a 10 percent to 40 percent increase. Most biodiesel users had not noticed a change in fuel efficiency. Three of 20 biodiesel users noticed small decreases in miles per gallon.

Differences between Users and Non-Users

Larger agencies and those operating in urban areas tend to be more likely to adopt alternatives than smaller, rural providers. Eighty-six percent of biodiesel and hybrid users responding to the survey are located in urban areas, and 78 percent of CNG users are urban. Agencies using biodiesel provide 50 percent more vehicle miles of service and nearly four times as many trips as those that do not use biodiesel. Similar comparisons can be made between hybrid users and non-users. Biodiesel, propane, CNG, and hybrid users also tend to run mostly fixed-route systems with a smaller percentage of demand response.

As some of the respondents noted, rural agencies are less likely to benefit from hybrid technologies since they provide longer trips at higher speeds with less stop-and-go travel. Urban driving, with repeated acceleration and braking combined with modest speeds, is more favorable for hybrid drive systems. The recapture of energy through regenerative braking is more efficient under urban driving conditions. Research has shown that the fuel consumption savings and emissions reductions from hybrids are small in rural areas and almost non-existent on highways, where the electric motor is hardly able to offer any additional support to the internal combustion engine (Alvarez et al. 2010). The characteristics of adopters reflect this argument. In addition to being mostly urban, fixed-route service, agencies with hybrid vehicles provide more trips per mile and per hour and travel fewer miles per hour than those transit providers without hybrid vehicles.

Not all of the differences between users and non-users can be explained by agency characteristics, however. Differences in individual attitudes and beliefs regarding perceived benefits and deterrents could also explain some differences.

Perceived Benefits

In general, users of alternative fuels and hybrids were more likely to identify benefits of adoption. For example, 71 percent of biodiesel users thought that improving public perception was a major benefit, compared to just 31 percent of non-users. E85 users were much more likely to view use of local resources and products as a major benefit (43% vs. 14%). Therefore, transit agencies located in areas where ethanol is produced could be more likely to use the fuel. In fact, four of the eight respondents using E85 are located in Iowa.

CNG users were more likely than non-users to view reducing emissions (80% vs. 53%), improving public perception (60% vs. 41%), and fuel cost savings (50% vs. 31%) as major benefits. Non-users were actually more likely to view positive performance impacts of the fuel as a major benefit. For hybrids, the most significant difference was that users were more likely to view improved public perception (70% vs. 53%) and fuel cost savings (79% vs. 57%) as major benefits, suggesting that these were motivating factors for the purchase of hybrid-electric vehicles.

Deterrents

Users and non-users also perceive some of the deterrents differently. For biodiesel, the most significant differences were regarding infrastructure costs and fuel supply. Fifty-three percent of non-users viewed infrastructure costs as a major deterrent to using biodiesel, compared to just 5 percent of users. Since there are no additional infrastructure costs required to adopt biodiesel, this result suggests non-users of biodiesel misperceive that they would have to modify their fueling equipment or vehicle engines to use the fuel. Two-thirds of non-users viewed the lack of an adequate and dependable fuel supply as a major deterrent compared to 19 percent of biodiesel users. Fuel supply may be a legitimate deterrent for wide-scale adoption, and these findings suggest that those transit providers in areas where biodiesel is more readily available are more likely to use the fuel.

For CNG, non-users were significantly more likely than users to view high vehicle cost (60% vs. 11%), development and implementation of new fuel infrastructure (79% vs. 33%), modifications to maintenance facilities (73% vs. 11%), adequate and dependable fuel supply (48% vs. 11%), and maintenance issues (47% vs. 0%) to be major deterrents. These perceived differences could be real or due to a lack of information, but actual differences in infrastructure and modification costs exist. CNG is more popular in warmer climates where fueling is performed outdoors with minimal infrastructure required to meet fire codes. In colder climates, where all bus storage, maintenance, and fueling operations occur indoors, the cost of retrofitting an existing facility for CNG to meet fire code requirements may be prohibitive. Many of the CNG users responding to the survey are from southern states, including four from California.

Regarding hybrid vehicles, non-users were found to be consistently more likely to view an issue as a deterrent than were those agencies that have purchased hybrids. Results suggest that some issues such as vehicle availability, depot modification costs, concerns about reliability and vehicle performance, and battery replacement costs could explain some of the differences between those agencies that have purchased hybrids and those that have not.

Differences between Urban and Rural Transit Providers

Rural transit providers may have different problems or challenges and may view the benefits differently. As noted, many of the responding agencies that use alternative fuels or hybrid vehicles are from urban areas. For example, 38 percent of urban agencies surveyed use biodiesel, compared to 12 percent of rural transit providers. Similarly, 35 percent of urban respondents operate a hybrid vehicle, compared to 8 percent of rural respondents. One exception is E85. Urban and rural providers are about equally likely to own a flex fuel vehicle, but the rural respondents were found to be more likely to use E85 in those vehicles.

Urban and rural transit providers face many of the same deterrents and have many of the same opinions on benefits and problems, but some differences exist. Adequate and dependable fuel supply was found to be a major deterrent for both urban and rural providers, but it is a greater issue for those transit agencies serving rural areas. Seventy-five percent of rural respondents cited it as a major deterrent for using biodiesel, compared to 46 percent of urban respondents. Similar responses were obtained for E85 (70% of rural respondents and 53% of urban), propane (69% rural, 35% urban), and CNG (61% rural, 35% urban). In each case, rural respondents were also more likely to indicate that lack of information is a major deterrent. Limited vehicle range was also a greater issue for rural transit providers regarding propane and CNG, making long-distance trips difficult. Vehicle range and limited access to fueling infrastructure were previously documented to be issues for rural providers using propane or natural gas vehicles in Texas (TTI 2007). In general, rural respondents were more likely to report deterrents for all alternatives.

Regarding benefits, urban respondents were consistently more likely to say that improving public perception is a major benefit. Rural respondents were generally more likely than their urban counterparts to identify benefits from using biodiesel and E85 but tended to be less likely to find benefits from using propane, CNG, or hybrids.

Factors Affecting Adoption

To investigate how agency characteristics or beliefs about benefits and deterrents have influenced adoption of biodiesel or hybrid vehicles, a binary logit model was used. The binary logit model is a type of discrete choice model that can be used to model an agency's decision to adopt technology (Ripplinger and Brandt-Sargent 2010). We assume that transit agencies make the decision to adopt technology based on its impact on social welfare. Social welfare, *W*, is a function of consumer surplus (CS), which is affected by various factors, *X*, and the technology employed by the transit agency, τ, and the profits of the agency, π, which are affected by another set of factors, *Z*, and technology, τ, as shown by Equation 1.

$$W_i = CS(X,\tau) + \pi_i(Z,\tau) \quad (1)$$

Using biodiesel or hybrid vehicles influences cost effectiveness by impacting costs paid for fuel, infrastructure, vehicles, maintenance, etc. They also impact the social cost of operating transit vehicles by reducing negative environmental externalities, such as air pollution, and thereby affect social welfare. An agency's perception about the benefits of an alternative fuel will influence how they perceive social welfare will be impacted by the use of that type of alternative fuel or vehicle. Results from the survey suggest that these factors influence the decision to adopt.

Two separate binary logit models were estimated for biodiesel and hybrid vehicle adoption. The dependent variable is a binary variable equal to one if the agency uses biodiesel or hybrid vehicles and zero otherwise. Adoption of E85, propane, or CNG was not modeled because not enough users of these fuels responded to the survey, so there were not enough observations to develop a model.

Explanatory variables include characteristics of the agency and opinions about benefits and deterrents. Agency characteristics that could influence adoption include the number of vehicles the agency owns, the number of vehicles miles of service provided, the number of vehicle hours of service provided, and whether they serve a rural or small urban area. It is expected that larger agencies, those with more vehicles, and those providing more miles and hours of service are more likely to use biodiesel or hybrid vehicles, and those in urban areas may also be more likely to adopt these alternatives. Larger agencies may be more likely to have the resources to consider and adopt these alternatives, and the benefits of hybrid technology are more advantageous in urban driving conditions.

It is also hypothesized that those agencies that identify greater benefits of biodiesel or hybrid adoption, such as emissions reductions or improved public perception, are more likely to choose those alternatives. Likewise, those that identify greater deterrents, such as increased costs or inadequate supply, are hypothesized to be less likely to adopt. Dummy variables are included in the model to represent respondents who considered a potential benefit as a major benefit or a potential deterrent as a major deterrent.

The estimated odds ratios from the binary logit models are shown in Table 2. Agency size variables were measured as the number of vehicles the agency operates and the thousands of miles and hours of service provided. The odds ratio for these variables is the estimated change in the odds of adoption with a one unit increase in the variable.

Results show that agencies that operate more vehicles and provide more vehicle miles of service were more likely to use biodiesel. Conversely, those that provide more hours of service, everything else held constant, were less likely to use biodiesel, indicating that agencies were less likely to use biodiesel if their service was spread out over more hours. In other words, those agencies providing more miles of service per hour were more likely to use biodiesel. The impacts of vehicles, vehicle miles, and vehicles hours on hybrid use were not found to be statistically significant.

Table 2. Results from Binary Logit Models of Adoption

	Biodiesel		Hybrids	
	OR	95% CI	OR	95% CI
Vehicles (number)	1.067***	1.021–1.116	1.016	0.983–1.049
Vehicle miles (thousand)	1.001*	1.000–1.002	1.000	1.000–1.001
Vehicle hours (thousand)	0.959**	0.925–0.995	0.994	0.973–1.015
Urban	74.698**	1.367–999.9	8.420*	0.948–74.76
Perceived benefits				
Emissions	32.043**	1.532–670.3	1.343	0.183–9.850
Energy dependency	0.322	0.033–3.122	0.146*	0.018–1.165
Local resources	0.525	0.034–8.138		
Public perception	33.154***	3.080–356.9	4.890*	0.762–31.37
Cost savings	0.525	0.008–8.069	5.113*	0.728–35.92
Deterrents				
Fuel cost	0.718	0.091–5.676		
Infrastructure cost/ Depot modification cost	0.119	0.004–3.436	0.090**	0.010–0.840
Fuel supply	0.061*	0.003–1.069		
Lack of information	0.913	0.016–53.44		
Fuel efficiency	0.775	0.020–30.43		
Vehicle cost			0.635	0.149–2.712
n=86				

Note: OR = odds ratio; CI = confidence interval.
**p <0 .10 **p <0 .05 ***p <0 .01*

Urban agencies were substantially more likely to use biodiesel (odds ratio 74.70) and hybrids (odds ratio 8.42). The odds of using biodiesel were 75 times greater, and the odds of adopting hybrids was 8.4 times greater if the agency operates in an urban area, everything else held constant.

Agencies that viewed emissions reductions as a major benefit of biodiesel were significantly more likely to use that fuel. Agencies that viewed reducing energy dependency as a major benefit of hybrid use were actually less likely to use hybrids, though the result was only marginally significant. In either case, the implication is that concerns about energy dependency do not motivate agencies to adopt either biodiesel or hybrids, even though some view biodiesel or hybrids as being beneficial in this regard. Agencies that consider improved public perception as a major benefit were significantly more likely to use biodiesel or hybrids. This result is especially significant for biodiesel. It appears counterintuitive that energy dependency concerns are not a significant determinant of adoption, while improving public perception is significant. One possible explanation is that whether or not they believe energy independence is important or if their decision to adopt will have a positive impact on reducing dependency on imported oil, transit agencies are more likely to be motivated by public perception.

Those who view fuel cost savings as a major benefit for hybrids were significantly more likely to use those vehicles. Findings show that beliefs about the benefits of emissions reductions, improved public perception, and costs savings are the greatest motivating factors for adoption.

Regarding deterrents, two significant results were found. Those agencies that listed depot modification costs as a major deterrent for hybrid use were significantly less likely to adopt, and those that cited lack of adequate and dependable fuel supply as a major deterrent for biodiesel adoption were significantly less likely to use that fuel. While other deterrents exist, the model did not find significant differences between users and non-users regarding their perceptions of those deterrents. Perhaps more significant results would be found with a greater number of observations. These results indicated that concerns about infrastructure costs and fuel supply were most likely to influence the decision to adopt biodiesel or hybrids. Whether these perceptions are valid and decisions are rational is another matter. Some perceptions may be correct while others are not. Since hybrids usually do not require significant facility modifications, the results suggest hybrid non-users could be misperceiving required infrastructure costs.

Factors Affecting Satisfaction with Biodiesel

An ordered logit model was used to estimate satisfaction with biodiesel for those agencies that use it. For this model, the dependent variable is the degree to which the agency is satisfied with their use of biodiesel, and it ranges from 1 to 5, with 1 being very dissatisfied and 5 being very satisfied. The explanatory variables include the size characteristics (vehicles, miles, hours), whether the agency operates in an urban or rural area, the number of years the agency has used the fuel, whether the agency provided any biodiesel-specific training, whether they change the blend during colder months, and the percentage of the fleet that uses biodiesel. It is hypothesized that larger agencies may have more resources to successfully adopt the new fuel and that those agencies that have more experience using biodiesel, provided training to employees, change the blend during colder months, and operate a higher percentage of the fleet on biodiesel are more likely to have success with the fuel, as defined by how satisfied they are with the fuel. Agencies that operate a higher percentage of their fleet with biodiesel are making a greater commitment to the fuel and, therefore, may be more successful. Previous research of CNG users found that those agencies with a higher percentage of their fleet operating on natural gas were more likely to have success with the fuel (Eudy 2002).

Many of the results were found to be statistically insignificant (Table 3). Two statistically significant results were found. Agencies with a greater number of vehicles and those that operate a greater percentage of their fleet with biodiesel were found to be more likely to have positive experiences with the fuel.

Table 3. Factors Affecting Satisfaction with Biodiesel Use, Results from Ordered Logit Model

	OR	95% CI
Vehicles (number)	1.119**	1.022–1.225
Vehicle miles (thousand)	0.998	0.993–1.002
Vehicle hours (thousand)	0.983	0.942–1.027
Urban	0.059	0.001–13.54
Years of experience	0.662	0.365–1.202
Training	0.348	0.012–9.769
Change blend	6.000	0.508–70.85
Percentage of fleet	1.070**	1.015–1.128
n=20		

Note: OR = odds ratio; CI = confidence interval.
**p <0 .10 **p <0 .05 ***p <0 .01*

There are a few possible explanations for how the percentage of fleet dedicated to biodiesel is related to satisfaction. One explanation is that fleets with a higher percentage of vehicles operating on an alternative fuel have a greater familiarity with the fuel and are better equipped to handle any difficulties. Another explanation is that agencies with positive experiences could be more likely to expand their use of the alternative fuel. Alternatively, agencies that commit to an alternative fuel may feel the need to justify that decision by overestimating the positive benefits.

This result does not mean that smaller agencies or rural agencies cannot or do not have success with biodiesel. A number of factors can contribute to the success agencies have with adopting new fuels or new technologies, and a lot can be learned from the smaller, rural systems that have had success.

Attempts were made to model satisfaction with hybrid vehicles, but no significant results were found, possibly due to limited data. Alternatively, it could be that those agencies dissatisfied with hybrid vehicles were largely unique cases that could not have been predicted by any agency characteristics or other factors. Similar models were not applied to other alternatives due to limited data.

Conclusion

Previous research has identified advantages and disadvantages from using alternative fuels and hybrid buses. However, less is known about the factors that motivate agencies to adopt these alternatives or the degree to which different deterrents prevent adoption, especially among small urban and rural transit agencies. In this study, survey responses from 115 transit systems in small urban and rural areas were received and analyzed.

Larger agencies and those operating in urban areas were found to be more likely to adopt alternatives than smaller, rural providers. It was also found that beliefs about benefits and deterrents have some influence on adoption. In general, users tended to be more likely to identify benefits. In particular, users of biodiesel, CNG, and hybrid vehicles were more likely to think that improved public perception is a major benefit. Regarding deterrents, non-users were substantially more likely to view infrastructure costs and adequate fuel supply as deterrents for biodiesel; vehicle costs, development of new fuel infrastructure, modifications to maintenance facilities, adequate fuel supply, and maintenance issues as deterrents for CNG; and vehicle availability, depot modification costs, concerns about reliability, and battery replacement costs as deterrents for hybrids.

Findings from a logit model of biodiesel and hybrid adoption indicated that beliefs about the benefits of emissions reductions, improved public perception, and costs savings were the greatest motivating factors for adoption, and concerns about infrastructure costs and fuel supply were the most likely to negatively influence the decision to adopt.

Additional research could investigate whether the perceived deterrents are valid. The deterrents may be valid in some areas and less valid elsewhere. For example, concerns by biodiesel non-users about infrastructure costs suggest a misperception about required investments. Providing more and better information to transit providers may reduce possible misperceptions and increase adoption rates.

The survey revealed a general satisfaction with use of alternative fuels and hybrid vehicles for those agencies that have adopted them, though some problems were identified. Significant deterrents also exist for many of the agencies that have not adopted any of these alternatives. Use was much less common in rural areas, and these deterrents would have to be addressed before widespread adoption occurs.

References

Alvarez, Robert, Peter Schlienger, and Martin Weilenmann. 2010. Effect of hybrid system battery performance on determining CO2 emissions of hybrid electric vehicles in real-world conditions. *Energy Policy* 38: 6919-6925.

Beer, Tom, Tim Grant, David Williams, and Harry Watson. 2002. Fuel-cycle greenhouse gas emissions from alternative fuels in Australian heavy vehicles. *Atmospheric Environment* 36: 753-763.

Eudy, L. *Natural Gas in Transit Fleets: A Review of the Transit Experience*. Golden, CO: National Renewable Energy Laboratory, 2002.

Federal Transit Administration. 2006. Alternative fuels study: A report to Congress on policy options for increasing the use of alternative fuels in transit vehicles. U.S. Department of Transportation.

Federal Transit Administration. 2007. Transit bus life cyle cost and year 2007 emissions estimation. U.S. Department of Transportation.

Humburg, D. S., T. J. Hansen, L. G. Schumacher, G. L. Mahapatra, G. L. Taylor, and B. T. Adams. 2006. Biodiesel use and experience among state DOT agencies. *Applied Engineering in Agriculture* 22(2): 177-184.

Mattson, Jeremy. 2012. Use of alternative fuels and hybrid vehicles by small urban and rural transit systems. DP-250, Upper Great Plains Transportation Institute, North Dakota State University.

Nylund, Nils-Olof, Kimmo Erkkila, Maija Lappi, and Markku Ikonen. 2004. Transit bus emission study: Comparison of emissions from diesel and natural gas buses. VTT Processes.

Ripplinger, David, and Bethany Brandt-Sargent. 2010. Technology adoption by small urban and rural transit agencies. Departmental Report No. 226, Upper Great Plains Transporatation Insitute, North Dakota State University.

Texas Transportation Institute. 2007. Alternative fuel vehicles at small urban and rural public transportation systems in Texas. White Paper, sponsored by the Texas Department of Transportation, College Station, TX: The Texas A&M University.

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Applying Structured Scheduling to Increase Performance in Rural Demand-Response Transportation

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Abstract

Many rural demand-response transportation systems have increased ridership to a level that the systems feel they need technology or increased scheduling and vehicle capacity. Instead of adding resources, capacity can be expanded and performance can be increased by applying a scheduling structure. The scheduling structure proposed in this research applies directly to systems that share specific geographic characteristics. For these areas, trips are assigned to runs based on time and location, which results in increased performance and vehicle utilization. The structure enables trips to be scheduled during the booking process using simple and easy-to-understand rules that allow the customer to select the appropriate route.

This research explains how to establish structured rural demand-response transportation service and enumerates its benefits through a case study consisting of actual service data. The case study shows a reduction in service miles by 27 percent due to implementation of structured scheduling.

Introduction

Rural demand-response transportation (DRT) is inefficient to deliver, time-consuming to schedule, and requires a large vehicle fleet whose capacity tends to be underutilized. Many rural DRT systems have increased ridership to a level that has led to the perception that technology or increased scheduling and vehicle capacity are warranted to meet the current demand. The greatest opportunity for increasing rural DRT performance and decreasing the scheduling effort is for transportation systems to structure the service instead of continually adapting to the stated demand. Structured service means that the rural DRT has planned a route structure by area and time to provide understandable, consistent service that meets the needs of the customers.

This research applies most directly to rural demand-response transportation systems that possess specific characteristics, including one, and only one, urban area in or near the center of the service area with the basic medical, employment, and shopping destinations; major roads that lead to the urban area; and a density that is high enough to allow service to all destinations within a reasonable time.

There are numerous benefits to structured service. The structure groups trips to runs, which increases performance and vehicle utilization while decreasing the demand for more vehicles. Where a structure exists, the trip is scheduled during the reservation/booking process using simple and easy-to-understand rules that allow the customer to select the most appropriate route.

Scheduling the trip when the reservation is placed reduces a substantial portion of the scheduling effort, as the confusing aspects of space and time are mitigated by the structure. Instead of seating potentially hundreds of trip requests to runs every day, the scheduler focuses on adding enhancements to improve the scheduled service.

To make a clear and quantifiable justification for implementing structured demand and help illustrate the concepts, a case study is presented using actual service data from a rural demand-response transportation system.

Methodology

Each methodology task first describes the methodology in general terms, then describes how the process applies to the case study site. This parallel structure enables replication of the methodology, while illustrating the structuring and enhancement process using a specific example.

Select a Site

To apply all of the recommendations in this research, the study site must have certain characteristics that enable the scheduling process to be structured according to the research recommendations. These characteristics include:

- The service area has one, and only one, urban area.
- The urban area contains basic medical, retail, and employment centers.
- The urban area is located in or near the geographic center of the service area.
- Major roads provide direct access to the urban area from the outlying areas.
- The urban area is sufficiently dense to allow a vehicle to provide service to all major destinations within a reasonable time.

These characteristics are not present in all rural DRT systems. For systems that have different characteristics, the conceptual process of structuring demand and applying enhancements still applies, but the structure may need to be altered to achieve optimal results.

Case Study: Lenoir County, North Carolina, is the case study site used to ascertain the benefits of structured rural demand-response transportation. Lenoir County Transit (LCT), based in Kinston (population 21,677 [U.S. Census 2010]), is a rural community transportation system that serves the general public, medical, and human services trips for Lenoir County (population 59,495 [U.S. Census 2010]). Kinston is the capital of the county and contains basic health services, employment, and shopping destinations for Lenoir County. Few services exist within the county outside of the Kinston area. It is situated just north of the Neuse River, which divides Lenoir County in half while generally flowing west to east. The majority of Lenoir County's population and services are north of the river, with the notable exception of the community college across the river to the southeast. Kinston is served north/south by US 258 and east/west by US 70.

In Fiscal Year 2011 (July 2010–June 2011), LCT provided 107,019 passenger trips, traveled 812,372 service miles, and operated 18 vehicles (primarily lift vans) (NCDOT 2012). The average cost per service mile was $1.33 in FY2011 (NCDOT 2012). LCT operates a deviated fixed route within Kinston with 16 roughly hour-long runs between 7 AM and midnight.

Preparing Origin/Destination Data

After selecting a site, trip data must be collected that includes origin and destination addresses, requested pickup/drop off times, and assigned runs. The addresses should include the physical street address and postal code, at a minimum. Optimally, the addresses will be collected as coordinate data to ensure accurate mapping.

The in-service area trips are split into two rows, with one line for the origin stop and one line for the destination stop. Trips that have an origin, destination, or both that are unable to be mapped due to incomplete or inaccurate addresses are removed. Out-of-service-area trips are removed, as these trips need to be served with a different structure than in-service area trips.

A time constraint code is added to each trip to make it easier to categorize trips based on the customer's needs. Demand-response trip data contains a pickup time and a drop off time, but only one of these times is defined by the customer, and thus, indicate the customer's need. Trips that originate at a customer's home are assigned a drop-off time constraint code, as it is likely that the customer is most concerned about when he/she arrives at the destination. Trips that terminate at a customer's home are deemed to be constrained by the pickup time.

The final step in preparing the data is to map the trip origins and destinations. The mapped origins/destinations show one point for the pickup and one for the drop-off. For this analysis, the data are mapped using a Geographic Information System (GIS). It is also possible to use Web-based mapping tools.

Case Study: LCT was able to provide one week's worth of data from August 2011. The week coincides with a state-mandated sampling period. The peak day (Wednesday) was selected for in-depth analysis. Roughly 10 percent of the trips were removed due to incomplete address information. There were a total of 344 usable trips for the Wednesday study period.

Determine Actual Service

It is essential to establish a baseline for comparison that enumerates the actual service provided by the rural DRT during the study period. The simplest and most consistent comparison using readily-available tools and data is to calculate the number of miles required to deliver the service. The number of passengers remains consistent between the actual service and the proposed service. Service hours are difficult to calculate, as assumptions must be made concerning the boarding and alighting times of passengers and groups of passengers.

It is possible to use the daily start and end odometers of the vehicles during the study period to calculate the miles only if 1) no trips were removed due to incomplete data and 2) no break/maintenance/fueling miles were incurred. If these situations exist, the most equitable method of calculating miles is to use GIS or an online mapping service to determine network miles using the pickup and drop-off times for each stop. The actual miles may not equate to service miles, but it does provide a level field for comparison.

In addition to the miles required to deliver the service, the peak and total number of vehicles used to deliver the service must be determined.

Case Study: For LCT data, it is not possible to use the daily start and end odometers to calculate miles because some incomplete addresses were removed. Instead, the miles are calculated by mapping every stop for every run in online mapping software. The stops were ordered according to how LCT performed them. It was not possible to know the exact path that the drivers used to travel between the stops, nor whether the vehicles returned to the depot during long stretches of inactivity. For these reasons, it is believed that the total miles of actual service is a conservative estimate. The actual service characteristics are displayed in Table 1.

Table 1. Actual Service Characteristics for Lenoir County Transportation

Vehicles	17
Peak Vehicles	17
Deviated Fixed-Route Trips	59
Demand-Response Trips	285
Total Miles	2,742

Develop a Geographic Service Structure

Creating service zones is the first step in structuring rural DRT service, with the central zone being the first zone to establish. The central zone should be as small as possible, yet contain all or almost all the potential destinations in the service area. A properly-defined central zone is essential to simplifying the scheduling process, as almost all trips from outer zones will terminate in the central zone for rural DRT systems with the previously-defined geographic characteristics.

Next, outer zone boundaries are developed based on natural breaks in the transportation network, such as rivers, ridges, and undeveloped areas. These zones should be centered on the primary road network used to access the central zone. Roads should not be used as zone boundaries, as this may result, for example, in one vehicle serving the east side of the road and another vehicle serving the west side. Splitting neighborhoods, small communities, and other areas with distinct identities should be avoided where possible.

Outer zones should be sized to create manageable service areas. If a service area is large, there may be two or more layers of concentric outer zones, resembling a dart board. For smaller service areas, outer zones may span from the central zone to the edge of the service area, exhibiting a pie shape. Whatever the configuration of the outer zones may be, it is essential that these zones be easily understandable to both the schedulers and the customers. It is also essential that almost all of the trips originating in the outer zones terminate in the central zone.

Case Study: The central zone for LCT contains the city of Kinston and a small section southeast of Kinston to incorporate the local community college. Ninety-five percent of the trips in the LCT service area originate or terminate in the central zone. The outer zones are pie-shaped and named according to ordinal directions. Figure 1 shows the zones and the origin and destination stops for the selected study day. There are eight outer zones. The zone directly to the south of the central zone (indicated by hatching) warrants special consideration, as three other zones pass through it to access the central zone. As it is not possible to efficiently distribute the land area in this zone to the three outer zones, trips originating/terminating in this pass-through zone will be served by the zone runs that pass through it (zones W, SW, and SE).

Structure Service

Once the geographic service structure is in place, the daily scheduling problem becomes easier to solve, as the trips are categorized in groups based on time and space. The scheduling problem then becomes a tabular problem instead of a space and time problem. Trip reservations are scheduled to the appropriate zone run as the reservations are booked. In addition to recording the reservation details, the booking agent will update the scheduling table to reflect the number of trips for each run.

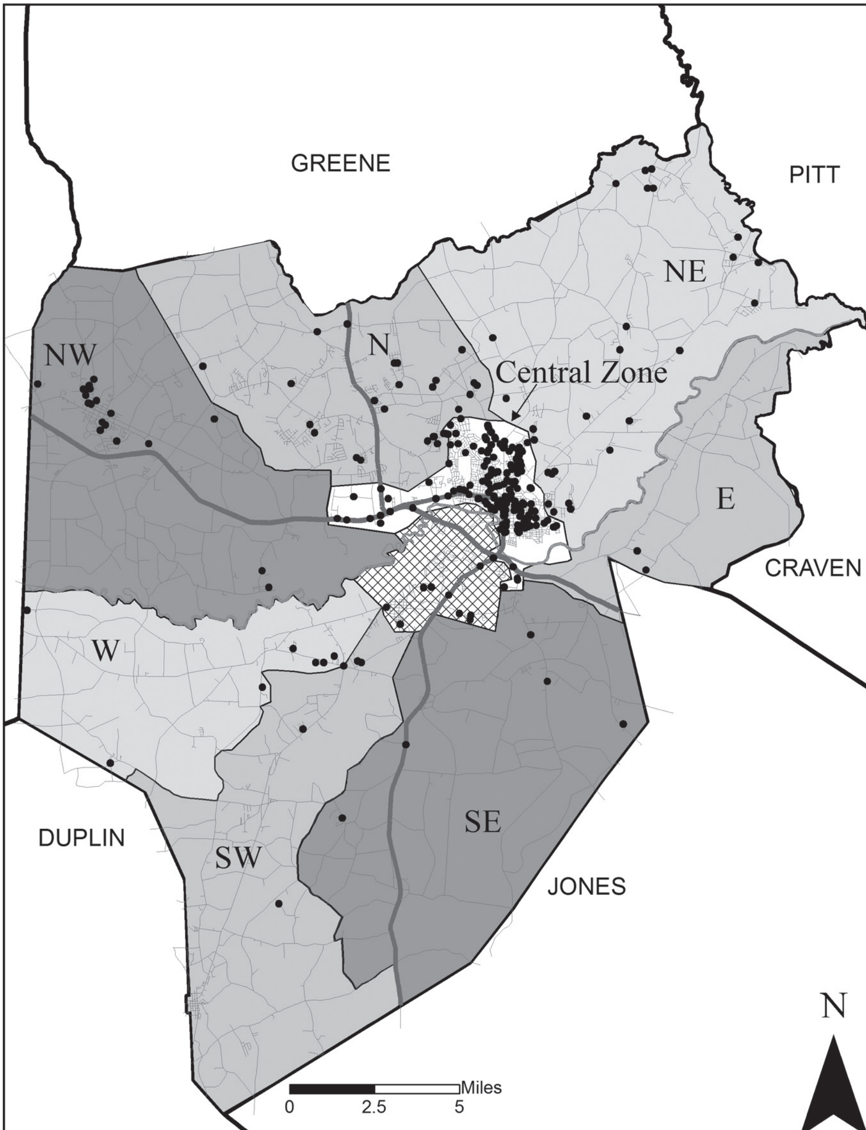

Figure 1. Zone-Based Scheduling Structure for Lenoir County

Before daily service begins, the scheduler must first look over the table to see if there are any issues with vehicle capacity and add runs if necessary. The scheduler then adds the short-term enhancements of eliminating unnecessary deadhead (empty or unloaded runs) and consolidating runs where possible. Finally, the scheduler must determine the appropriate order to serve the trips within the zone-based runs.

Will-call trips are a common cause of inefficient service delivery. The structured demand makes it simple to schedule will-call trips. When the request is called in, the staff person can look at the scheduling matrix to determine the next run available to serve the trip request and assign the trip to that run. The end result of a scheduling structure will be a more efficient schedule and an easier scheduling process.

Develop a Scheduling Table

To begin structuring the service and creating a scheduling table, a service time period that meets the needs of the customers must first be determined. Each zone should be eligible to be served by inbound and outbound runs once per time period. For example, a run may originate in each outer zone every hour, and a run may terminate in each outer zone every hour (originating in the central zone). This example structure means that there may be two vehicles in each zone at every time period (one inbound, one outbound). Trips may also originate and terminate within the central zone every time period.

It is necessary to develop rules to assign trips to a zone-based run structure, as the customer's stated demand for a service time will not initially fit neatly into the zone structure. For example, a trip that is desired to be picked up in an outer zone and dropped off in the central zone at 9:30AM needs to be assigned to either the runs that originate in the outer zone at 8AM or 9AM. Because the customer most likely needs to be at the destination by 9:30AM, the trip should be assigned to the 8AM run, which drops off all passengers in the central zone by 9AM.

After developing the assignment rules, each trip is categorized by time period into the zone-based run structure. The structured service may then be displayed in a table with the columns displaying runs and the rows displaying the time period, and the total trip requests in the associated run cells (see the case study section for an example). Runs that originate in the outer zones are inbound, while runs that originate in the central zone are outbound.

Trips that originate and terminate in the central zone and trips that originate and terminate outside of the central zone are assigned to their own runs. If fixed-route or deviated fixed service exists, all trips should remain assigned to these services. The remaining trips are assigned to sweeper vehicles that stay within the central zone. Rural sweeper vehicles are used to capture trips that do not originate/terminate in the central zone.

Additional runs are added where demand exceeds capacity. For example, more than one central zone sweeper may be required to serve the trip demand. A simple method of determining how many runs are required to serve the demand is to establish a maximum trip count that can be adequately served by the run within the constraints. Each zone may have unique maximum trip counts depending on the constraints.

Next, a starting and ending point should be established for each run. Each run that originates in the outer zone must have an accompanying run the previous time period that terminates in the outer zone. In addition, each run that terminates in the outer zone must have an accompanying run the following time period to move the vehicle back to the central zone. Sometimes starting and ending points must be reached with deadhead runs.

After categorizing the trips into the structured service, GIS or web-based mapping is used to calculate the average number of miles required to serve each zone. To be conservative, it is assumed that each outbound run originates at the depot and each inbound run terminates at the depot.

Finally, the number of runs for the new service structure is multiplied by the average number of miles to determine the structured miles. This number will serve as the baseline for comparison with the actual service and the enhancements. In addition, the total runs for each time period are calculated, which determines the number of vehicles required per time period.

At this point, a scheduling table has been established based on the customer's stated demand. The next steps are to add enhancements to improve efficiency.

Case Study: Trips for LCT are assigned to runs based on a time period of one hour. The scheduling goal for rural zones was to have roughly four trips per run to allow for all trips to be served within the one hour timeframe. Urban zones were allowed six trips per run. Deadhead runs with zero trips are established to move the vehicles to/from the appropriate zones. To provide adequate service, LCT requires up to four central zone sweepers and two rural sweepers in addition to the deviated fixed route. LCT requires a *maximum of two vehicles per rural zone, one inbound and one outbound. There is one instance (NW in at 7 AM) where six trips are served by one rural run. As the preceding outbound run is empty, it should not be an issue for this run to serve 6 trips. The total structured miles for LCT is essentially the same as the total actual miles (2,742 actual miles; 2,735 structured miles), and total and peak number of vehicles is identical (17).*

Table 2. Scheduling Table Based on Stated Demand

	CENTRAL ZONE					RURAL ZONES																	
Hour	Dev. Fixed Route	Sweeper 1	Sweeper 2	Sweeper 3	Sweeper 4	NE In	NE Out	N In	N Out	NW In	NW Out	W In	W Out	SW In	SW Out	SE In	SE Out	E In	E Out	Sweeper 1	Sweeper 2	Total Trips	Total Runs
4		4					0		0													4	3
5		4	3			3	0	1					0									11	6
6		6	6	6		3	0		1		0	2	0						0			24	10
7	11	6	6	5	5	3		3	4	6	1	3	0		1		1	2		5	4	66	17
8	5	6	5				0	4	1	1	1	4		0		0	0					27	12
9	3	5				3	0	1		2						1	0					15	8
10	4	5	4			2	0		1				1			1						18	8
11	2	3				1	3	1	3		0	0	1		0							14	10
12	3	5				1	4	1	0	1	0	0		2	1							18	11
13	3	6				0	1	1	1	1	2			0	0					1		16	11
14	7	5	5	5		0	2	0	2	2				3	0		2			1		34	13
15	8	5	5	5		0	3	4	2		1		1	1		0				3	2	40	14
16	2	5				1	2	0	0	0	3	0					1			1		15	11
17	7	5	4	4		0	1	2	3	1	2		1			0	1		2			33	14
18	2					1		0		0	1	0				0	3	0				7	9
19										0						0						0	2
20	0																					0	1
21	1																					1	1
22	0																					0	1
23	1																					1	1
Total Trips	**59**	**70**	**38**	**25**	**5**	**18**	**16**	**18**	**18**	**14**	**11**	**9**	**4**	**6**	**2**	**2**	**8**	**2**	**2**	**11**	**6**	**344**	
Total Runs	**16**	**14**	**8**	**5**	**1**	**13**	**13**	**12**	**12**	**10**	**10**	**7**	**7**	**5**	**5**	**7**	**7**	**2**	**2**	**5**	**2**		**163**
Average Miles	18	18	18	18	18	17	17	12	12	19	19	21	21	15	15	12	12	15	15	23	23		
Total Miles	288	252	144	90	18	226	226	149	149	186	186	145	145	75	75	82	82	30	30	113	45		**2735**

Add Enhancements

Once the scheduling process is structured, it is relatively simple to add performance enhancements. The structure is essential, however, as understanding the disparate pickup and drop-off demands stated by the customers is difficult for the scheduler to process as trip requests increase.

There are two categories of enhancements, long-term and daily. Long-term enhancements include structuring demand and outstationing vehicles. Daily enhancements include eliminating unnecessary deadhead runs and consolidating runs with low trip counts.

Demand for trips outside of the structured service times and locations should be tracked to assist with updating the scheduling structure in the future. Updates to the structure should be considered on a regular basis to ensure that the transit system is responding to the needs of its customers.

In this research, enhancements were applied only to rural zones that serve the central city. Central city runs and rural sweeper runs must be dealt with using different scheduling processes than what is proposed in this research. For example, increasing fixed-route service or redesigning the service may reduce the number of central city sweeper runs, while implementing a hub-and-spoke service design or brokerage may eliminate the need for rural sweeper vehicles. However, these scheduling and planning methods are outside of the scope of this research.

Long-Term Enhancement 1: Structured Demand

Instead of adapting to the stated demand of the customers (who have no framework within which to place their demands), the rural DRT should structure the demand using historical data. By categorizing trips into geographic service areas and times, it is possible to determine the demand for service within a zone at each time period. Rural DRTs should determine service demand within the structured zone-based framework and establish a structured demand-based service where runs with little or no ridership are eliminated.

It is preferable to have the same structured demand for each weekday. First, a scheduling table for each weekday should be developed. Next, runs with low demand should be eliminated. If service fluctuates greatly between weekdays, it may be necessary to develop scheduling tables for individual days of the week.

Case Study: By eliminating runs with little or no demand, 30 runs were removed from service, resulting in a savings of 452 miles (25%). Six runs were eliminated for the NE zone, 6 for the N zone, 10 for the NW zone, 2 for the W zone, 2 for the SW zone, and 4 for the SE zone. To accomplish this structure, only 27 trips were moved from their original demanded time. Trips initially assigned to the eliminated runs were moved to the preceding run before noon and the following run after noon to account for trip time constraints. Central zone runs and rural sweeper runs are not affected by the structured demand enhancement. The final structured service, after unproductive runs were removed, is shown in Table 3. This structure became the baseline for determining the impact of the enhancements outlined in the following section. The proposed structured demand results in a savings of 453 miles and $602 per day, when compared to the actual miles.

Table 3. Scheduling Table Based on Structured Service

	CENTRAL ZONE					RURAL ZONES																	
Hour	Dev. Fixed Route	Sweeper 1	Sweeper 2	Sweeper 3	Sweeper 4	NE In	NE Out	N In	N Out	NW In	NW Out	W In	W Out	SW In	SW Out	SE In	SE Out	E In	E Out	Sweeper 1	Sweeper 2	Total Trips	Total Runs
4		4					0		0													4	3
5		4	3			3	0	1					0									11	6
6		6	6	6		3	0		1		0	2	0						0			24	10
7	11	6	6	5	5	3		3	4	6	2	3	0		1		1	2		5	4	67	17
8	5	6	5				0	4	1	3		4		0		0	0					28	11
9	3	5				3	0	1								2						14	6
10	4	5	4			3			4				2									22	6
11	2	3					3	2				0			0							10	6
12	3	5				1	4		0		0			2								15	7
13	3	6				0		1		2					1					1		14	7
14	7	5	5	5			3		3		2			3	0		2			1		36	11
15	8	5	5	5		0	3	4		2			1	1		0				3	2	39	13
16	2	5				1			2		4	0					1			1		16	8
17	7	5	4	4			3	2	3	1			1			0			2			32	11
18	2					1		0			3	0					4	0				10	7
19										0						0						0	2
20	0																					0	1
21	1																					1	1
22	0																					0	1
23	1																					1	1
Total Trips	**59**	**70**	**38**	**25**	**5**	**18**	**16**	**18**	**18**	**14**	**11**	**9**	**4**	**6**	**2**	**2**	**8**	**2**	**2**	**11**	**6**	**344**	
Total Runs	**16**	**14**	**8**	**5**	**1**	**10**	**10**	**9**	**9**	**6**	**6**	**6**	**6**	**4**	**4**	**5**	**5**	**2**	**2**	**5**	**2**		**135**
Average Miles	18	18	18	18	18	17	17	12	12	19	19	21	21	15	15	12	12	15	15	23	23		
Total Miles	288	252	144	90	18	174	174	112	112	112	112	124	124	60	60	59	59	30	30	113	45		**2289**

Long-Term Enhancement 2: Outstationing Vehicles

Outstationing vehicles can be more easily accomplished in a structured demand environment because it is known when and where each run will begin and end. In pure demand-response service, it is difficult to outstation vehicles because the service changes on a daily basis. Depending on the structure, oustationing vehicles in safe, secure locations may result in decreased deadhead miles from the depot to the start of a run originating in a rural zone and vice versa. Outstationing requires that a morning outstationed run be accompanied by an afternoon run that terminates at the outstation site.

Case Study: Table 4 shows the scheduling table with both long-term enhancements, which becomes the baseline scheduling table for adding daily enhancements. Outstationing seven vehicles results in a 16 percent reduction in miles (233 miles) from the structured service baseline. Zones NE, N, NW, SE, and E each have one outstationed vehicle. Zone W has two outstationed vehicles. Zone SW has no outstationed vehicles. Adding outstationing to the structured service results in an estimated daily savings of $310 (233 miles x

$1.33 cost per mile) from the structured service scheduling table. Together, the long-term enhancements of outstationing and structuring the service resulted in an estimated daily savings of $912 (686 miles x $1.33 cost per mile), when compared to the actual service.

Table 4. Scheduling Table Based on Long-Term Enhancements

	CENTRAL ZONE					RURAL ZONES																	
Hour	Dev. Fixed Route	Sweeper 1	Sweeper 2	Sweeper 3	Sweeper 4	NE In	NE Out	N In	N Out	NW In	NW Out	W In	W Out	SW In	SW Out	SE In	SE Out	E In	E Out	Sweeper 1	Sweeper 2	Total Trips	Total Runs
4		4																				4	1
5		4	3			3	0	1														11	5
6		6	6	6		3	0		1			2										24	7
7	11	6	6	5	5	3		3	4	6	2	3	0		1		1	2		5	4	67	17
8	5	6	5				0	4	1	3		4		0		0						28	10
9	3	5				3	0	1								2						14	6
10	4	5	4			3			4				2									22	6
11	2	3					3	2				0			0							10	6
12	3	5				1	4		0		0			2								15	7
13	3	6				0		1		2					1					1		14	7
14	7	5	5	5			3		3		2			3	0		2			1		36	11
15	8	5	5	5			3	4		2			1	1		0				3	2	39	12
16	2	5				1			2		4						1			1		16	7
17	7	5	4	4			3	2	3	1			1			0			2			32	11
18	2					1					3						4					10	4
19																						0	0
20	0																					0	1
21	1																					1	1
22	0																					0	1
23	1																					1	1
Total Trips	**59**	**70**	**38**	**25**	**5**	**18**	**16**	**18**	**18**	**14**	**11**	**9**	**4**	**6**	**2**	**2**	**8**	**2**	**2**	**11**	**6**	**344**	
Total Runs	**16**	**14**	**8**	**5**	**1**	**9**	**9**	**8**	**8**	**5**	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**1**	**1**	**5**	**2**		**121**
Average Miles	18	18	18	18	18	17	17	12	12	19	19	21	21	15	15	12	12	15	15	23	23		
Total Miles	288	252	144	90	18	157	157	99	99	93	93	83	83	60	60	47	47	15	15	113	45		**2056**

Daily Enhancement: Consolidate Runs

Once the long-term enhancements are in place, the scheduler must focus on improving the daily schedule by consolidating runs. There are two steps to consolidate runs. The first step is to eliminate unnecessary deadhead runs, which occur when one vehicle deadheads empty in one direction while another deadheads empty in the other direction. The next step is to combine runs in adjacent zones that have low trip counts. Runs must be consolidated in pairs, as there is no benefit to consolidating two outbound runs only to have to add an additional deadhead run to account for the following inbound runs.

Consolidating runs will likely result in mileage increases, as a vehicle may need to travel across zones. The increased miles must be considered by the scheduler when determining the effectiveness of run consolidation.

Case Study: It is assumed for LCT that every consolidated run results in an additional 10 miles of travel for the unconsolidated run to account for travel between zones. In addition, runs may only be consolidated if they are in the same or adjacent zones. With these rules in place, four runs are consolidated to eliminate unnecessary deadhead runs and two are consolidated due to low demand. The deadhead runs that were eliminated are N Outbound at noon, NE Inbound at 1 PM, SW Outbound at 2 PM, and SE Inbound at 3 PM. The low demand runs that were consolidated are W and SW Outbound at 7 AM; and W and SW Inbound at 8 AM. Table 5 shows the scheduling table after applying the daily enhancements. The consolidation of 6 runs resulted in a total savings of 62 miles from the long-term enhancement baseline after 60 additional miles are added to account for travel between the zones. The total savings of structuring demand and adding enhancements is 748 miles (a 27% reduction from actual miles) and an estimated daily savings of $995. In addition, the simplified scheduling process resulted in a reduction of staff time and effort.

Table 5. Scheduling Table with Daily Enhancements

	CENTRAL ZONE					RURAL ZONES																	
Hour	Dev. Fixed Route	Sweeper 1	Sweeper 2	Sweeper 3	Sweeper 4	NE In	NE Out	N In	N Out	NW In	NW Out	W In	W Out	SW In	SW Out	SE In	SE Out	E In	E Out	Sweeper 1	Sweeper 2	Total Trips	Total Runs
4		4																				4	1
5		4	3			3	0	1														11	5
6		6	6	6		3	0		1			2										24	7
7	11	6	6	5	5	3		3	4	6	2	3			1		1	2		5	4	67	16
8	5	6	5				0	4	1	3		4				0						28	9
9	3	5				3	0	1								2						14	6
10	4	5	4			3			4				2									22	6
11	2	3					3	2				0			0							10	6
12	3	5				1	4				0			2								15	6
13	3	6						1		2					1					1		14	6
14	7	5	5	5			3		3		2			3			2			1		36	10
15	8	5	5	5			3	4		2			1	1						3	2	39	11
16	2	5				1			2		4						1			1		16	7
17	7	5	4	4			3	2	3	1			1			0			2			32	11
18	2					1					3						4					10	4
19																						0	0
20	0																					0	1
21	1																					1	1
22	0																					0	1
23	1																					1	1
Total Trips	**59**	**70**	**38**	**25**	**5**	**18**	**16**	**18**	**18**	**14**	**11**	**9**	**4**	**6**	**2**	**2**	**8**	**2**	**2**	**11**	**6**	**344**	
Total Runs	**16**	**14**	**8**	**5**	**1**	**8**	**9**	**8**	**7**	**5**	**5**	**4**	**3**	**3**	**3**	**3**	**4**	**1**	**1**	**5**	**2**		**115**
Average Miles	18	18	18	18	18	17	17	12	12	19	19	21	21	15	15	12	12	15	15	23	23		
Extra Miles								10				10		10									
Total Miles	288	252	144	90	18	139	157	109	87	93	93	93	62	55	45	35	47	15	15	113	45		**1994**

Conclusions

Scheduling rural demand-response trips is difficult, time-consuming, and often results in inefficient service delivery and inefficient use of resources. As rural demand-response service increases, providers often look to increase vehicle and scheduling capacity to handle the increased demand and complexity. Instead of adding resources, capacity can be expanded and performance can be increased by applying a well-planned scheduling structure.

This research explains how to establish structured rural demand-response transportation service and enumerates its benefits through a case study consisting of actual service data for a rural DRT system. Once a structure is in place, the trips are assigned to runs as they are booked. Grouping trips according to a structure based on historical demand simplifies the scheduling process by transforming it to a tabular exercise instead of a space-and-time exercise. The scheduler need not be concerned with seating trips on runs and can instead focus on improving the efficiency of the daily service.

Applying the recommendations cited in this research to the case study site results in a daily savings of 748 miles (a 27% reduction in miles) and $995. The same number of trips is served, and the service structure is based on the customer's stated demand for service.

References

NCDOT Public Transportation Division. 2012. *FY11 Operating Statistics* (unpublished).

United States Census. 2010. Census Quickfacts 2010. Accessed April 24, 2012. http://quickfacts.census.gov/qfd/states/37/37107.html.

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Evaluating the Competitiveness of Intercity Buses in Terms of Sustainability Indicators

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Abstract

A sustainable transportation system is the one that is designed based on environmental awareness, social equity, and economic opportunities. Public transportation, in general, and intercity transit, in particular, are playing very significant roles for communities to reach their sustainability goals. Of the available intercity transit services, buses are showing a noteworthy growth to be a competitive mode in terms of sustainability indicators. After several decades of decline, intercity bus services are growing at an increasing rate, overtaking other intercity services. This paper, based on data from various sources and existing literature, makes a comparative analysis of intercity bus services with its competitors, mainly train transit (Amtrak) and air services. The analysis result shows that intercity buses are standing out to be an environmentally-friendly, economically-viable, and socially-inclusive mode of long-distance travel (especially to rural and small communities and for persons with no car).

Introduction

Intercity buses, as defined by the Federal Transit Administration, are regularly-scheduled bus services for the public that operate with limited stops over fixed routes connecting two or more urban areas not in close proximity, and that make meaningful connections with scheduled intercity bus service to more distant points, if such service is available (FTA 2007; Kack et al. 2011). The KFH Group, a transit consultancy group, broadly includes services provided by private for-profit firms and services provided by public transit grant recipients that have a "meaningful" connection to the network. A "meaningful connection" has generally been defined by the KFH Group as a connection with a wait time of less than two hours (KFH Group 2007).

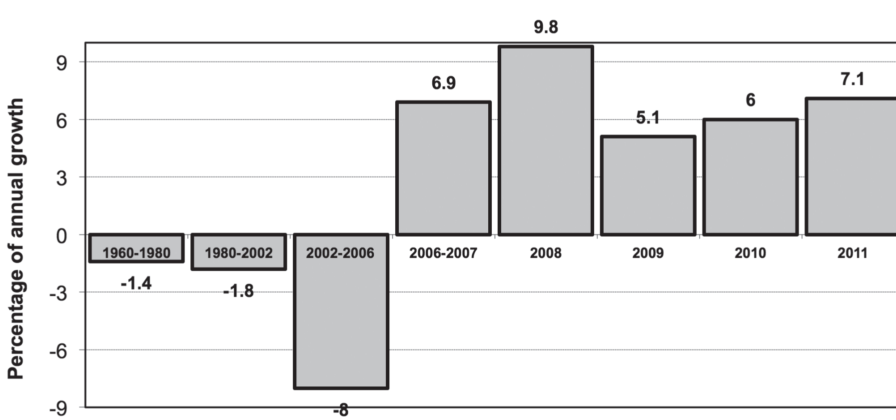
In whatever way it is understood, intercity bus transportation has seen growing usage in rural areas and smaller communities as part of the public transportation network. Intercity buses link smaller communities within a region and also link rural communities to larger urban areas. The industry is also known to provide service for communities where access to car ownership is limited. Although U.S. cities lost a significant amount of their scheduled intercity service over the last several decades, recently, the industry is experiencing noteworthy growth. Despite this recent growth, intercity bus services are having this success without public subsidy, unlike Amtrak, municipal transit systems, and a few specialized programs that receive federal or state assistance. Services rely on passenger fare revenue to cover operating and capital costs and to generate an adequate return on investment to attract capital for growth (Fravel 2003).

Several research papers and policy documents suggest that intercity buses are the environmentally-friendly, economically-viable, socially-acceptable and safe means of long-distance travel when compared to other intercity modes of travel. Thus, this paper aims to discuss the sustainability aspect (in terms of social, economic, and environmental indicators) of intercity buses in comparison with other intercity modes of travel. The data are gathered from various sources and existing research and policy documents. The Intermodal Passenger Connectivity Database (IPCD) and other data from the Bureau of Transportation Statistics (BTS) are used for analyzing the geographic coverage of intercity transportation. The IPCD is a nationwide data table of passenger transportation terminals, with data on the availability of connections among the various scheduled public transportation modes at each facility. In addition to geographic data for each terminal, the data elements describe the availability of rail, air, bus, transit, and ferry services. These data have been collected from various public sources to provide the nationwide measurement of the degree of connectivity available in the national passenger transportation system. Secondary data were gathered from various sources and analyzed to make a sound comparison between intercity buses and other long-distance travel modes using pre-defined sustainability indicators.

Background of Intercity Buses

Historical Background

Historical accounts suggest that scheduled intercity bus service began in 1913 when passengers were carried between the towns of Hibbing and Alice in northern Minnesota (Wrenick 2011). By 1926, there were 4,040 intercity bus industries nationwide offering scheduled bus service for passengers traveling between cities (Damuth 2008). As documented by Schwieterman et al. (2007), the intercity bus sector slumped in the 1960s in response to the decline of central cities, improvements to other modes of transportation (especially personal automobile), and increases in household incomes. By the mid-1970s, the number of passengers using scheduled bus services was falling sharply, and the industry's image was fast deteriorating (Schwieterman et al. 2007). U.S. cities lost nearly one-third of their scheduled intercity service between 1960 and 1980, with more than half of the remaining services being lost between 1980 and early 2006 (Figure 1). However, by late 2007, the sector was going through a significant rebirth and was expanding at the fastest rate in more than 40 years. Today, as documented by O'Toole (2011) and Schwieterman et al. (2007), growth by low-cost carriers such as Megabus and the renewed strength of Greyhound and other conventional lines suggests that there is a noticeable increase in demand (O'Toole 2011; Schwieterman et al. 2007). Consequently, the efficiency of airports and rail stations is being enhanced by intermodal connecting service provided by intercity bus operators. In 2007, 3.4 percent of the intercity bus miles were airport shuttle service miles (Damuth 2008).

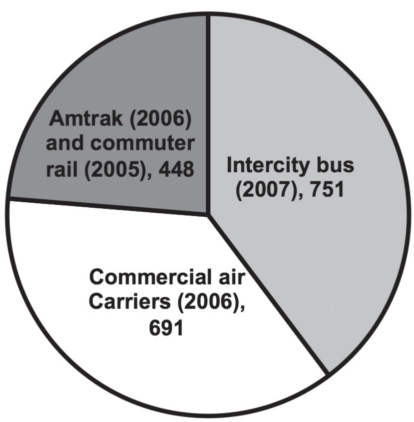


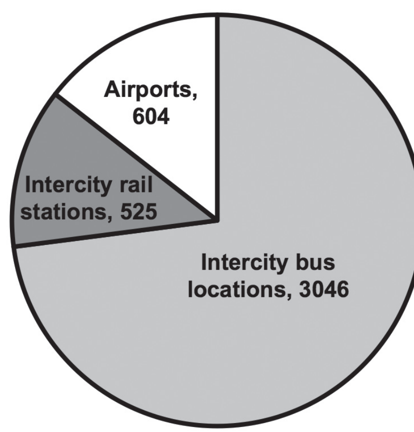
Source: Schwieterman 2010

Figure 1. Percentage annual growth and decline of intercity bus service

Current State

According to a report by Nathan, Inc., intercity buses provided 751 million passenger-trips in 2007, 9 percent more than the number of U.S. certificated commercial air carriers and almost 2 times more than Amtrak and commuter rail combined (Figure 2). Nationally, locations served by intercity buses include more than five times the number of airports and intercity rail stations (Figures 3 and 4). Also, according to Figure 4(a), produced from the Intermodal Passenger Connectivity Database (IPCD), the intercity buses offer a flexible service to more distributed locations in a given city. In that way, the intercity bus industry is known in its coverage of rural communities. Intercity buses cover 89 percent of rural residents, while air service covers 70 percent and intercity rail covers only 42 percent. For 14.4 million rural residents, intercity buses are the only available mode of intercity commercial transportation service (IPCD; BTS; Damuth 2008).





Source: Motorcoach Census 2008

Figure 2. Passenger trips (in millions)

Figure 3. Number of intercity facilities

The intercity bus was the only intercity mode to grow significantly in 2011, making it the fastest-growing form of intercity transportation for the fourth year in a row. This marks the fourth consecutive year that scheduled bus service grew faster than other modes of intercity transportation (McKonne 2011).

According to a recent report from DePaul University on intercity transportation (Schwieterman et al. 2011), rising awareness of new services, escalating fuel costs, and a modest economic recovery during the latter part of the year 2011 allowed the intercity bus industry to accelerate its rate of growth in 2011. The report also noted that curbside operators, most notably BoltBus and Megabus, introduced a number of new routes in 2011, while Greyhound expanded its premium “Express” service. This expansion, coupled with increased marketing efforts, led to heightened brand recognition and a growing public acceptance of bus travel (Schwieterman et al. 2011). Curbside operators in 2011 account for 778 daily bus operations in the continental United States, up from 589 a year before. The significant growth of curbside services was attributed primarily to the creation of three new hubs and incremental expansion from established hubs. Curbside operators, which avoid traditional stations in favor of curbside pickup while emphasizing Internet ticketing and express service between major cities, have been one of the country’s fastest-growing intercity transportation sectors in recent years (Klein 2011; Schwieterman et al. 2011).

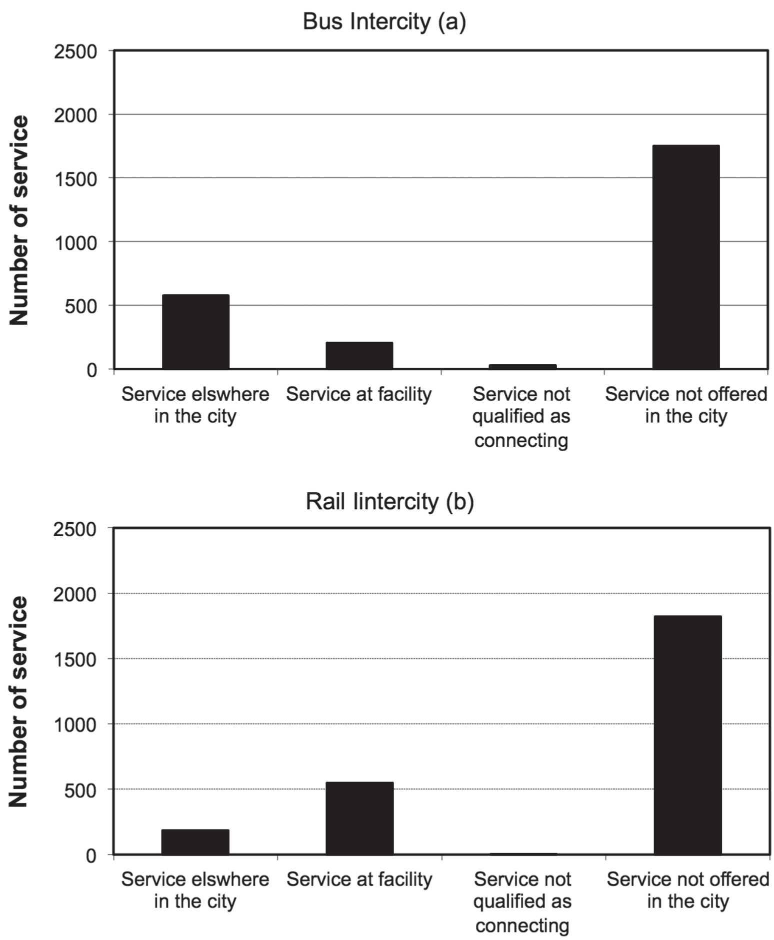
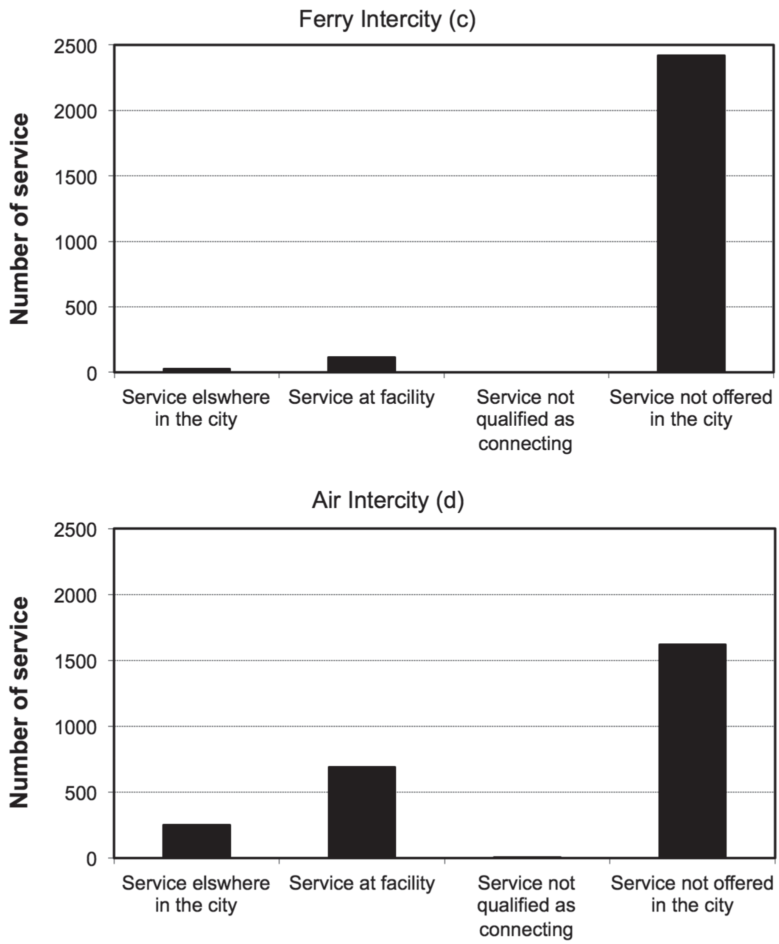


Figure 4. Intercity transit facilities



Source: The Intermodal Passenger Connectivity Database (IPCD), BTS 2012

Figure 4 (continued). Intercity transit facilities

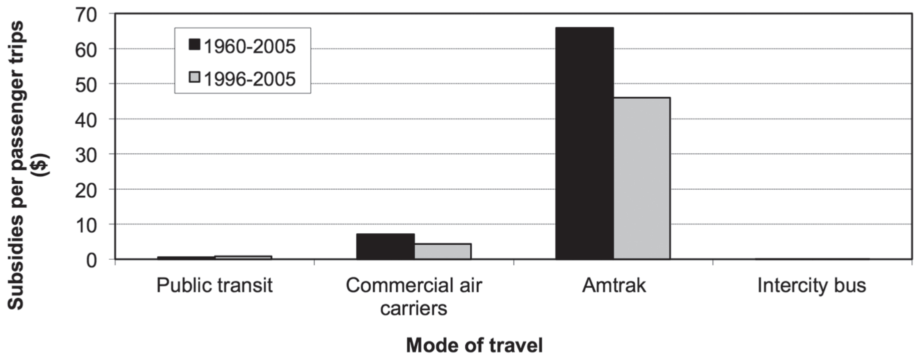
Sustainability Indicators

Sustainable communities are those that can provide opportunities to a viable economy, environmental protection, and social equity. Most literature on sustainability generally agrees that the whole idea of sustainability could be based on three components: the three E's: economic, environment, and equity. In the following section of this paper, the three E's are used to analyze the competitiveness of intercity bus in comparison with other intercity modes of travel.

Economic Indicators

The economic argument for intercity bus service emanates from the fact that the intercity bus industry is a least-subsidized mode while generating revenue and supporting the creation of new jobs. In 2007, ticket sales to tourists and spending on new intercity buses generated $55 billion in sales, which supported 792,700 jobs (Bourquin 2008; Bureau of Economic Analysis). Generally, consumer and industry spending stimulates local economies, thus promoting economic growth and opportunity. For example, according to a report from Guerrilla Economics, LLC, in West Virginia (2008), $40.3 million in spending, 1,300 jobs, and $4.0 million in state and local tax revenues were attributable to intercity bus charter and tour visitors in 2006. In southwestern Pennsylvania, $39.2 million in spending, 1,030 jobs, and $4.2 million in taxes were due to intercity bus charter and tour visitors in 2006. In Sevier County, Tennessee (the Pigeon Forge area), $89.2 million in spending, 2,100 jobs, and $8.9 million in taxes were due to intercity bus charter and tour services in 2005. These are just three of hundreds of regions throughout the country where local economies benefited from visitors who traveled by intercity bus (Guerrilla Economics, LLC 2007a; Guerrilla Economics, LLC 2007b; Damuth 2008).

It is undeniable that other intercity transport services (rail and air) also contribute to the local and regional economies a great deal. However, the distinction between intercity buses and other long-distance travel modes is that intercity buses' economic contributions come at virtually no cost to the government. Unlike other transportation industries, the intercity bus industry has received no federal subsidy. According to recently-published documents, from 1996 through 2005, public transit and commercial air passenger transportation received nearly all the subsidy. However, Amtrak received the highest subsidy per passenger trip and passenger mile. From 1996 through 2005, the intercity bus industry received just $0.06 of federal subsidy per passenger trip. In contrast, public transit received nearly 13 times more, commercial air carriers received 72 times more, and Amtrak received nearly 800 times more subsidy than the intercity bus industry (Figure 5) (O'Toole 2011; Damuth 2008).



Source: Nathan Associates, Inc., 2008

Figure 5. Subsidies per passenger trips (2005 dollars)

Environmental Indicators

Another measurement of sustainability is the benefit of a mode of travel in terms of its contribution to environmental protection. Many studies agree that intercity buses are an environmentally-friendly mode of transportation. Intercity bus passenger miles per gallon of fuel are more than twice the fuel efficiency of commuter and intercity rail and more than four times greater than domestic air carriers and transit buses (Figure 6). Intercity bus emission of CO2 gases, linked to global warming, are lower than any other modes. Other modes produce three to four times more emissions (Figure 8) (M. J. Bradley & Associates 2008). O'Toole (2001), citing from Transportation for Tomorrow, stated that intercity buses use less than 1,000 British Thermal Units (BTUs) per passenger mile, while intercity passenger trains use more than 2,500. Also, diesel-powered Amtrak trains produce roughly 2.5 times as much carbon emis¬sions as intercity buses (O'Toole 2011).

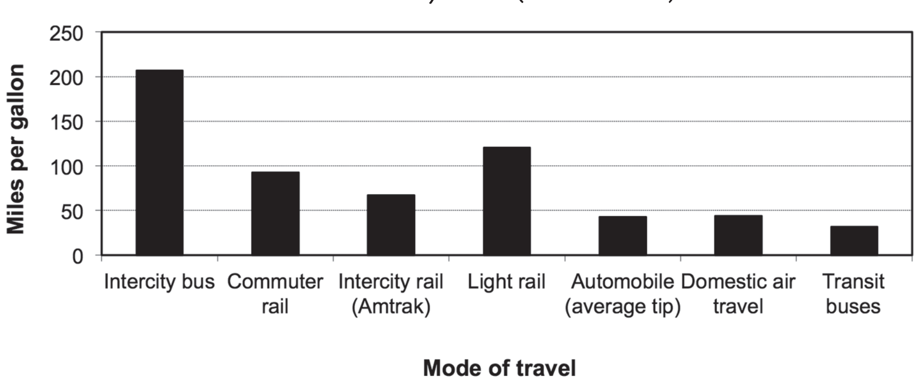


Figure 6. Passenger miles per gallon

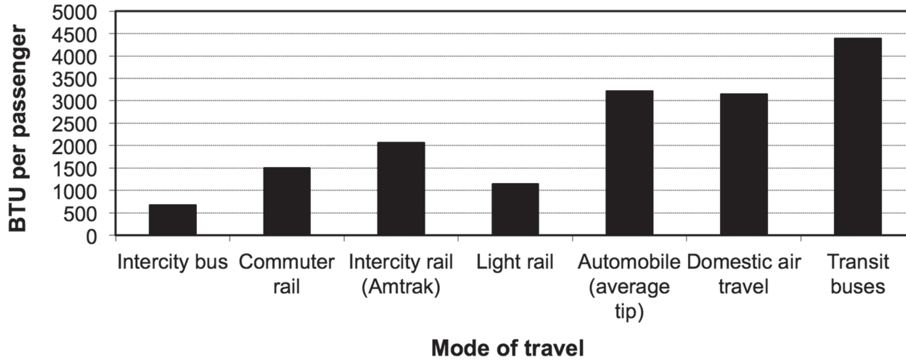


Figure 7. BTUs (British Thermal Units) per passenger mile

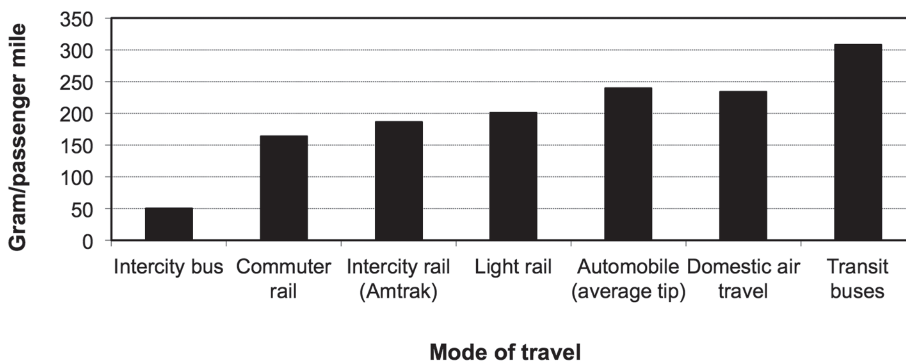


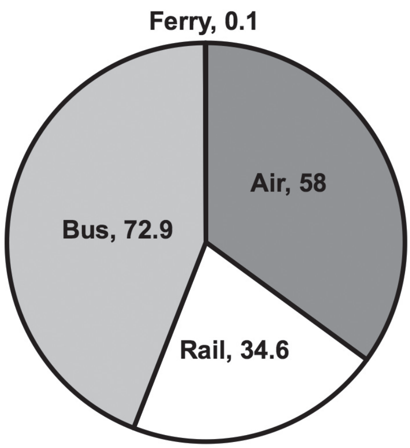
Figure 8. Carbon dioxide emissions (gram per passenger mile)

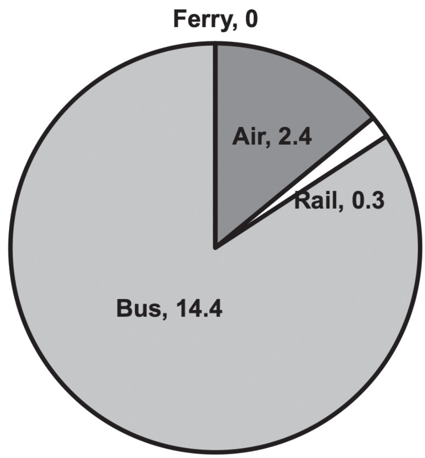
Equity Indicators

Rural Coverage

Rural communities can be disadvantaged by the transportation system due to their distant proximity from urban areas where the transportation services are concentrated. Intercity bus provides scheduled intercity services to many rural and small town communities (in many cases, the only service for those communities) (Bureau of Transportation Statistics 2005). Intercity bus transportation provides a particularly critical service for smaller communities in which air or passenger rail travel options are not available. It also provides a transportation option that may be more affordable than air or rail, when these are available, which is significant for many residents in rural areas (Transportation Research Board 2002).

Figures 9 and 10 show the percentage of rural population covered by each mode for all the 50 states combined (Bureau of Transportation Statistics 2005). Also, a map created based on the Intermodal Passenger Connectivity Database shows that intercity buses have a deeper penetration to rural areas than rail transit (Figure 11).



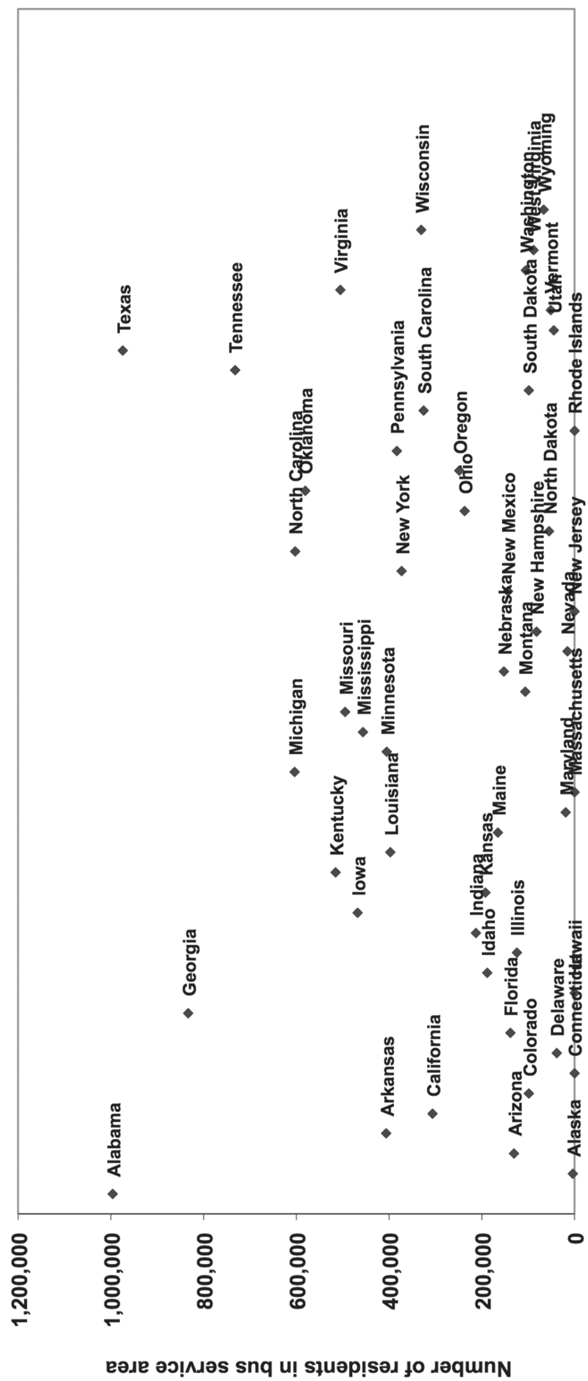


Source: BTS 2005

Figure 9. Scheduled rural intercity transportation—total rural population coverage (millions)

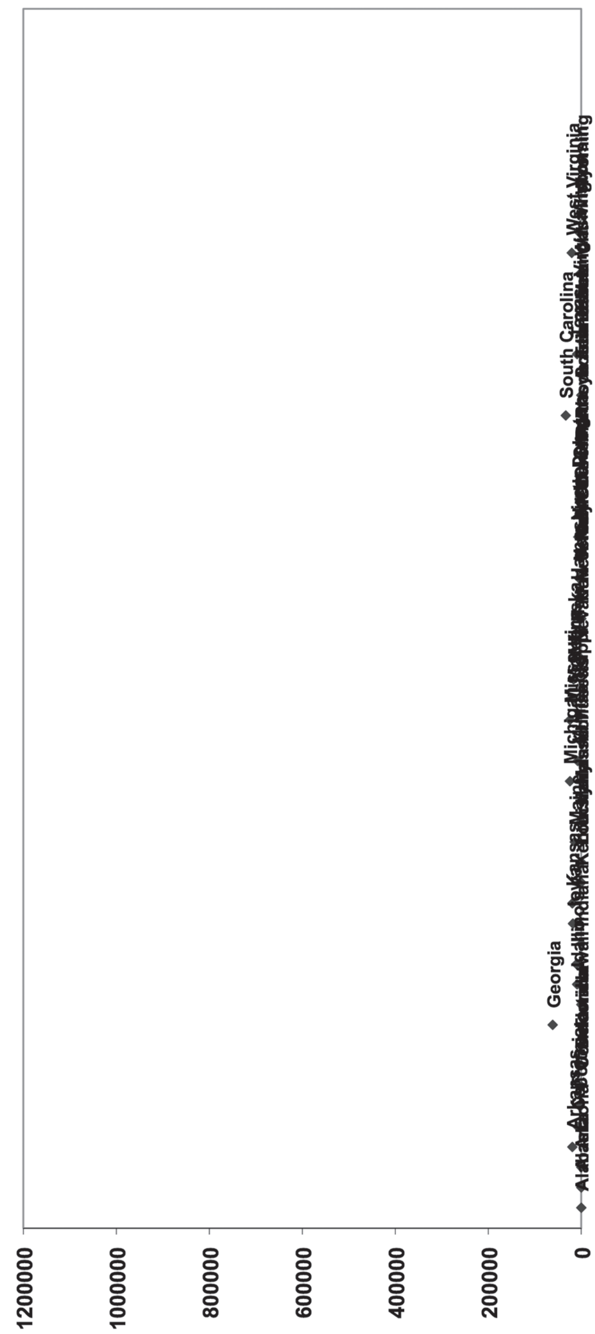
Figure 10. Scheduled rural intercity transportation—sole mode for rural population (millions)

Generally speaking, intercity bus has the deepest penetration within rural America. Figures 12–14 show the numbers of rural residents living within a reach of a particular intercity mode. Figure 12 shows that there are many rural residents living within intercity bus service areas, and Figures 13 and 14 show that only few rural residents have access to rail and transit services. The intercity bus network covers 88.5 percent of the total U.S. rural population and 89 percent of the rural population in the 48 contiguous states. (Some state governments provide funds for intercity bus services through the Federal Transit Administration Section 5311(f) formula grants program.) In most states, intercity buses serve a greater share of the rural population than the other modes. The only exceptions are in several Northeast states where air or rail service covers a slightly higher percentage of the population and in Alaska where air service has much deeper penetration of rural areas (Figures 12–14).



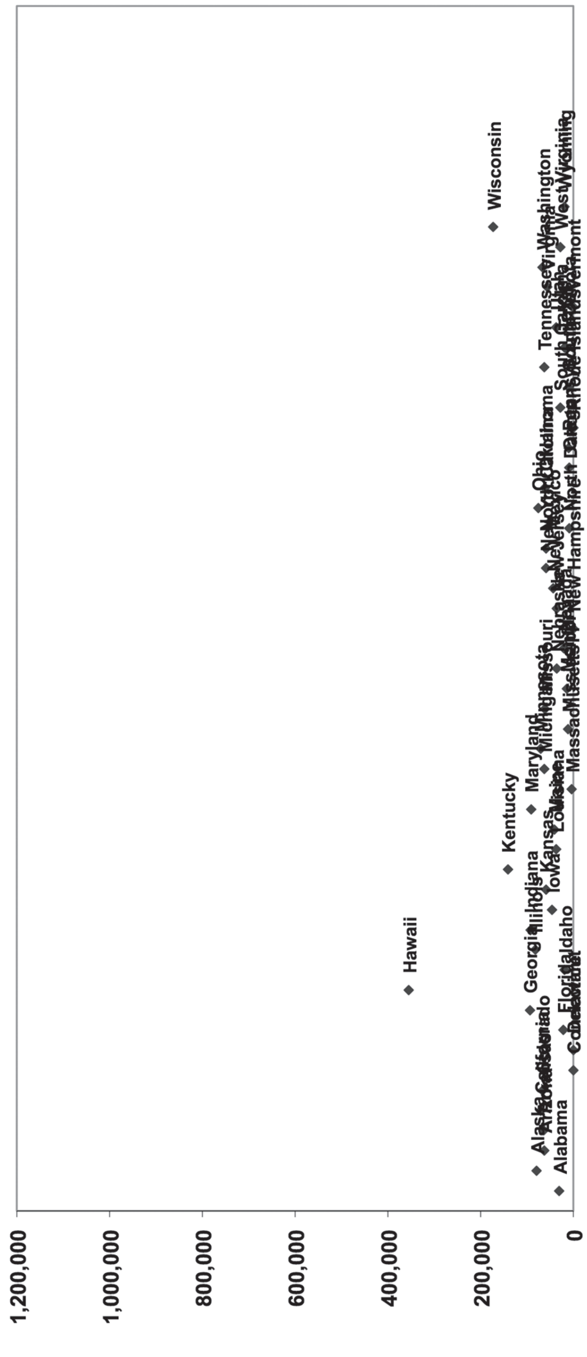
Raw data source: U.S. DOT, Research and Innovative Technology Administration, BTS April 2005

Figure 11. Number of rural residents in BUS service area only (not in air, rail, or ferry areas)



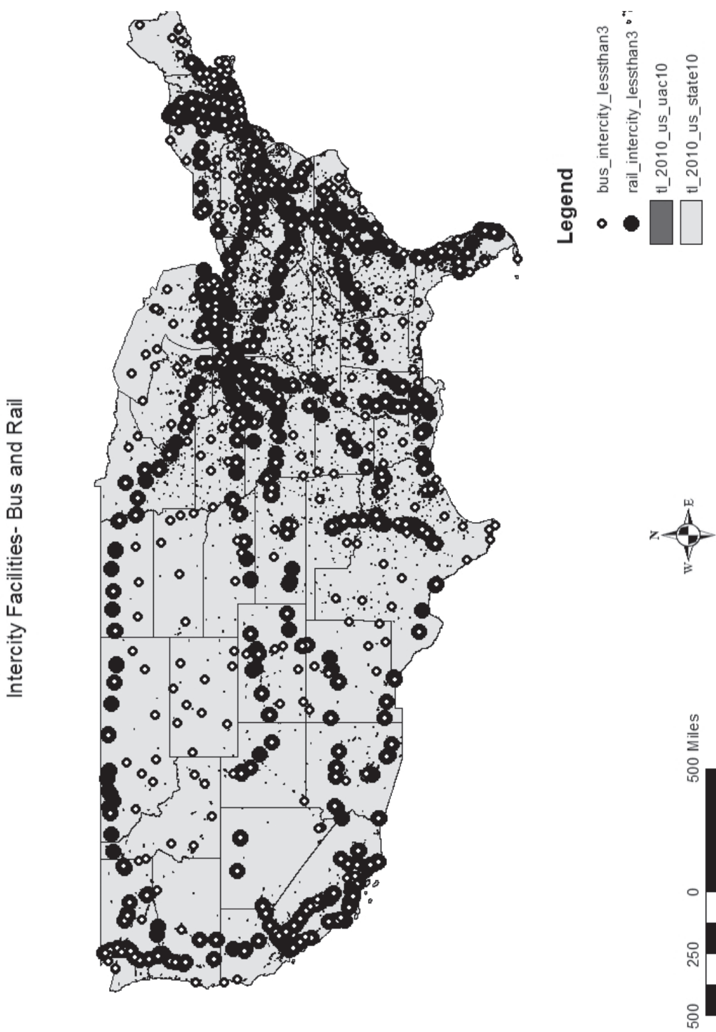
Raw data source: U.S. DOT, Research and Innovative Technology Administration, BTS April 2005

Figure 12. Number of rural residents in RAIL service area only (not in air, bus, or ferry areas)



Raw data source: U.S. DOT, Research and Innovative Technology Administration, BTS April 2005

Figure 13. Number of rural residents in AIR service area only (not in rail, bus, or ferry areas)



GIS by the author, source: The Intermodal Passenger Connectivity Database, BTS

Figure 14. Intercity bus and rail facilities

The intercity bus industry covers 100 percent of the rural population in 2 states, over 90 percent in an additional 20 states, and over 80 percent in another 10 states. There are only 4 mainland states where less than 70 percent of the rural population has intercity bus access, but even in these states, bus covers more of the population than the other modes (Table 1 and Figures 11–14). Approximately one in five rural residents who have access to intercity transportation (16.4 million) is within the coverage area of only a single intercity mode. For most of those people (13.5 million), intercity bus provides the sole access to commercial intercity transportation (BTS 2005).

Table 1. Scheduled Rural Intercity Transportation Coverage by Mode

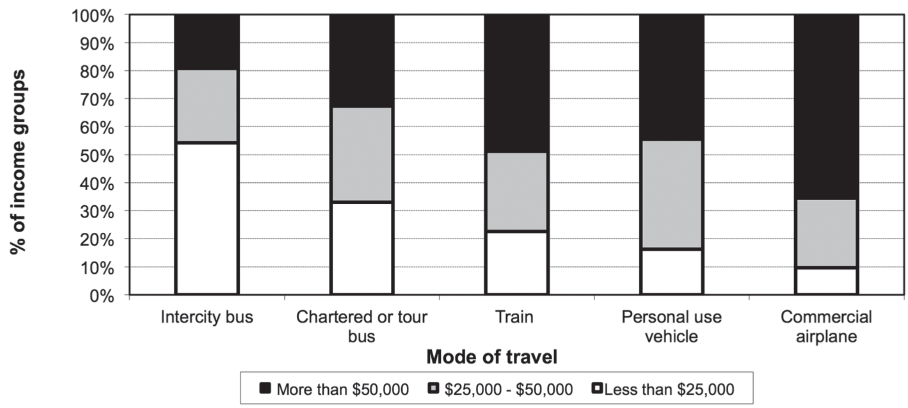
Percent of Rural Population Covered	Number of States			
	Air	Rail	Bus	Ferry
100% of rural population	4	1	2	0
90–99% of rural population	3	1	20	0
80–89% of rural population	8	1	10	0
70–79% of rural population	7	3	12	0
60–69% of rural population	13	5	1	0
50–59% of rural population	7	3	3	0
40–49% of rural population	5	9	1	0
30–39% of rural population	3	8	0	0
20–29% of rural population	0	11	0	0
1–19% of rural population	0	5	0	2
No coverage of rural population	0	3	1	48

Source: BTS, 2005

Intercity buses also offer low fares and travel options for persons without personal vehicle. Intercity bus passengers tend to be more transit-dependent than passengers of other intercity modes. Data from the Bureau of Transportation Statistics' American Travel Survey of 1995 show that regular intercity bus riders are more likely to be under 24 years old or over 60 years old than travelers on other modes. They are also more likely to have lower household incomes than those using other intercity modes and less likely to have a vehicle (Fravel 2003).

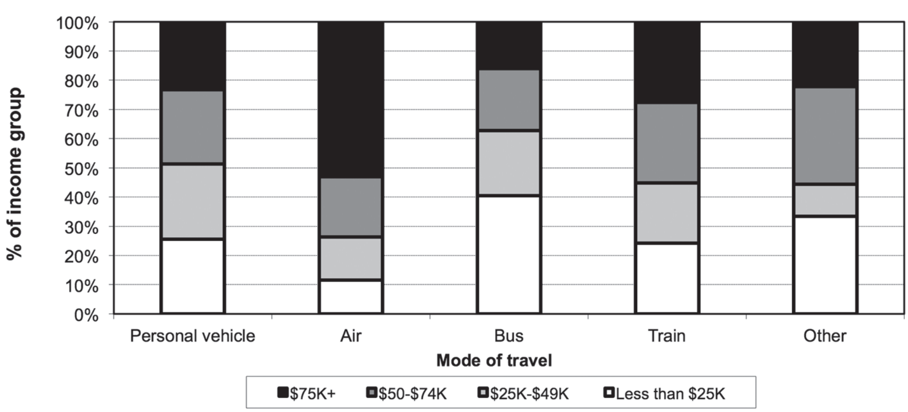
Intercity buses provide affordable transportation service, extending opportunities to the broader community. Over half (54.2%) of all long-distance intercity bus passenger trips and one-third (33.1%) of all long-distance charter or tour bus trips are taken by households with annual incomes less than $25,000. In contrast, only 9.7

percent of commercial airplane trips are taken by households with annual incomes less than $25,000. Nearly two-thirds (65.5%) are taken by households with annual incomes exceeding $50,000 (Figures 15 and 16) (Damuth 2008).



Source: 1995 American Travel Survey, BTS, U.S. DOT, October 1997

Figure 15. Distribution of long-distance trips by mode and annual household income



Source: U.S. DOT, BTS

Figure 16. Long distance trips by mode for household income groups

Safety

Social sustainability concerns with the basic needs and a good quality of life for all members of the community. Safety is one measure of quality of life. To this end, research indicates that intercity buses are a safe mode of transportation. According to Damuth (2008), among all passenger transportation modes, the intercity bus fatality rate is the lowest (0.5 fatality per 100 million vehicle miles). For passenger cars, the fatality rate is more than twice as high, and for U.S. air carriers, the fatality rate is nearly three times higher. For passenger trains, the fatality rate is nearly 16 times higher than the rate for intercity buses. Intercity buses suffer almost 80 percent fewer fatalities per billion passenger miles than Amtrak. From 1999 to 2008, intercity buses suffered 0.3 passenger fatalities per billion passenger miles, compared with 1.4 for Amtrak and 1.1 for urban transit buses (Damuth 2008).

Summary and Conclusion

Intercity bus services are an integral part of the overall surface public transportation system that meets long-distance travel demand. The industry has enjoyed a recent increase in ridership and a wide recognition by the public. It is playing a vital role in connecting major cities with each other and with rural and small-town communities. A review of literature and data analysis in this study shows that intercity buses are not only the fastest-growing industry but also a prominent mode in terms of sustainability indicators (as it is summarized in Table 2). Intercity buses are helping communities reach sustainability goals. Although other intercity transportation modes are playing undeniably significant role in catering a long-distance travel demand, the recent surge of intercity buses spark a renewed interest in its competitiveness in terms of sustainability indicators.

With the percentage of the older adult population increasing and two-thirds of them are living in small communities, the role of intercity buses in flourishing, with services to older residents unprecedented. In a time where various data sources indicate that the low income groups are expanding, intercity buses could be a viable choice for those who are less fortunate and do not own a car. Intercity bus is a better alternative form of transportation that is significantly less expensive than driving. In a broader sense, if the future requires the creation of a community that sustains itself, an intervention area will need to be creating a sustainable transportation system. To this end, intercity buses could be a promising mode of travel in terms of social, economic, and environmental advantages over other intercity modes. Any effort to create a “less driving” society should encourage intercity buses, along with other intercity travel modes, to reduce fuel consumption and global warming pollution.

Table 2. Summary of Intercity Transportation in Terms of Sustainability Indicators

The Three E's	Indicators	Intercity Bus	Rail/ Amtrak	Air Service	Information Sources
Economic	Subsidy per passenger mile (1996–2005)	$0.1 (2005 dollars)	$19.2 (2005 dollars)	$0.5 (2005 dollars)	Nathan Associates 2008
	Passenger out-of-pocket cost	Lower	low	high	NA
Environment	Passenger mile per gallon	200	70	48	M. J. Bradley & Associates 2008
	Energy (BTU) per passenger mile	600	2100	3200	M. J. Bradley & Associates 2008
	CO2 emissions (grams per passenger mile)	50	180	230	M. J. Bradley & Associates 2008
Equity	Service to rural communities (% of rural communities using service)	89%	42%	71%	USDOT; BTS 2005
	Service to low income groups (% of users with annual salary of < $25,000)	54.2%	22.6%	9.7%	American Travel Survey 1995
	Safety (passenger fatalities per billion passenger miles b/n 1999–2008)	0.3	1.4	0.9	Damuth 2008

References

Bourquin, Paul. 2008. Motorcoach Census 2008: A bench¬marking study of the size and activity of the motorcoach industry in the United States and Canada in 2007. Nathan Associates for the American Bus Association.

Bureau of Economic Analysis. "Travel and tourism data files 1998-2007." http://www.bea.gov/industry/tourism_data.htm.

Bureau of Transportation Statistics. 2005. Scheduled intercity transportation: Rural service areas in the United States. U.S. Department of Transportation, Research and Innovative Technology Administration (RITA).

Bureau of Transportation Statistics. 2012. The Intermodal Passenger Connectivity Database. U.S. Department of Transportation, RITA.

Damuth, Robert. 2008. The economic impacts and social benefits of the U.S. motorcoach industry: Binding the nation together by providing diverse and affordable services to everyone. Nathan Associates, Revised Draft.

Damuth, Robert. 2011. Federal subsidies for passenger transportation, 1960-2009: Focus on 2002-2009. Nathan Associates, Inc.

Federal Transit Administration (FTA). 2007. FTA Circular 9040.1F. Federal Transit Administration, Washington, D.C.

Fravel, Frederic D. 2003. Intercity Bus Links: Moving into New Territory. TR News 225.

Guerrilla Economics, LLC. 2007. The economic impact of motorcoach tourism in Southwestern Pennsylvania. American Bus Association Foundation.

Guerrilla Economics, LLC. 2007. The economic impact of motorcoach tourism in West Virginia. American Bus Association Foundation and West Virginia Division of Tourism.

Kack, David, Zhirui Ye, Jaydeep Chaudhari, and Levi Ewan. 2011. Montana intercity bus service study. FHWA/MT-11-005/8211.

KFH Group, Inc. 2007. California statewide rural intercity bus study. California Department of Transportation, Sacramento.

Klein, Nicholas J. 2011. More than just a bus ride: Curbside intercity buses. Paper presented at the 90th TRB Annual Conference.

McKone, Jonna. 2011. America's fastest growing form of transit: The intercity bus. TheCityFix.

M. J. Bradley & Associates. 2011. Updated comparison of energy use & emissions from different transportation modes. American Bus Association.

O'Toole, Randal. 2011. Intercity buses the forgotten mode. Policy Analysis No. 680, CATO Institute.

Schwieterman, Joseph P., Lauren Fischer, Sara Smith, and Christine Towles. 2007. The return of the intercity bus: The decline and recovery of scheduled service to American cities, 1960–2007. School of Public Service Policy Study, DePaul University.

Schwieterman, Joseph P. 2010. The intercity bus: America's fastest growing transportation mode: 2010 update on scheduled bus service. School of Public Service Policy Study, DePaul University.

Schwieterman, Joseph P., Lauren Fischer, Caitlin Ghoshal, Paige Largent, Nicole Netzel, and Marisa Schulz. 2011. The intercity bus rolls to record expansion: 2011 update on scheduled motor coach service in the United States. School of Public Service Policy Study, DePaul University.

Transportation Research Board. 2002. Effective approaches to meeting rural intercity bus transportation needs. TCRP Report 79.

Wrenick, Frank E. 2011. *The Streamline Era Greyhound Terminals: The Architecture of W. S. Arrasmith*. Jefferson, North Carolina: McFarland Publishing.

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Statewide Rural-Urban Bus Travel Demand and Network Evaluation: An Application in Tennessee

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Abstract

This paper examines the characteristics of intercity bus riders within Tennessee and proposes methods to identify service gaps and prioritize network expansion, particularly focusing on rural-urban connections. Data were collected through an on-board survey and compared with intercity auto trips. Compared to personal auto users, intercity bus riders are more likely to be of minority races, unemployed, unable to drive, and from low-income households. Five demand levels were determined based on the population distribution with these characteristics. The service areas of existing bus stops were identified and compared with the high demand areas. The result shows that an insufficient number of stops are located in high demand area. Still, approximately 80 percent of stops connect to meaningful destinations such as hospitals. The results imply that bus stations are well-connected to destinations but poorly connected to potential riders. Changes to the current network could better cover high-demand areas.

Introduction

Scheduled intercity bus service declined by one-third between 1960 and 1980, and remaining service declined by half between 1980 and early 2006 in the United States (Schwieterman et al. 2007). With rising travel demand, escalating gasoline prices, and Federal Transit Administration (FTA) 5311(f) funding for intercity bus agencies to provide or continue service, the industry is beginning to see more ridership. In recent years, fixed-route and scheduled intercity bus service have experienced a renaissance. It was rated as the fastest-growing mode of intercity transportation, outpacing air and rail transportation in 2010 (Schwieterman and Fischer 2010). In Tennessee, an Intercity Bus Demonstration Program was implemented in 2008 in response to growing public intercity travel needs, particularly focused on connecting rural and urban areas. There is a growing number of fixed-route, scheduled intercity bus services in the state. In the context of this study, we focus on intercity buses operating within the state of Tennessee and not directly connecting to different states, even though they do feed interstate bus and air terminals. In general, the intercity bus services described in this paper are short-haul buses that connect rural regions with urban centers.

Approaches to modeling intercity and interstate travel have evolved over the decades. Several early papers applied econometric methods to investigate choice behavior (Ashiabor, Baik, and Trani 2007; Koppelman 1989; Morrison and Winston 1985; Stopher and Prashker 1976). Because of jurisdictional and funding boundaries, within-state rural transit is a special class of transit service that deserves special study. However, little contemporary research has been directed to within-state intercity bus services, particularly in the context of recent demographic changes and growth in demand. This paper investigates emerging rural-urban bus travel patterns. A framework is presented to supplement locally-collected bus rider data with general long-distance travel described in the National Household Travel Survey (NHTS) (representing very few intercity bus trips) and apply this method to the Tennessee bus network. The paper describes results of intercity bus rider surveys that explore rider and trip characteristics of intercity bus users and contrasts those results with intercity car travel from the NHTS. Those data were used to estimate and map high demand regions to provide a framework to analyze rural-urban intercity bus service and connectivity between potential riders and their destinations. The paper highlights previous relevant research in the next section, followed by a description of the survey methods.

Previous Intercity Bus Studies

Intercity Travel Demand Model Review

A few papers have presented mode choice modeling approaches for intercity surface travel. Ashiabor et al. (2007) reviewed disaggregate nationwide travel demand modes developed by Stopher and Prashker (1976), Grayson (1981), Morrison and Winston (1985), and Koppelman (1989) between 1976 and 1990. All four models used versions of National Travel Surveys (NTS), and they included bus as one of the transportation modes. The fifth attempt to model nationwide travel demand was carried out by Ashiabor et al. (2007), who developed a logit model based on 1995 American Travel Survey (ATS). However, both the 1977 NTS and 1995 ATS collected information only on trips of 100 miles or more, eliminating intercity trips shorter than 100 miles, which includes most in-state Tennessee intercity bus trips.

Fravel et al. (2011), in "Toolkit For Estimating Demand For Rural Intercity Bus Service" (TCRP Report 147), introduced a toolkit to estimate demand for rural intercity bus corridors. The toolkit includes two demand estimation models, a regression model and a trip rate model, both of which give more accurate results for current rural intercity bus services than previous efforts to model intercity bus demand. However, this toolkit has limitations that cannot be used for regional transit, which includes much of the rural-urban bus service.

A Minnesota intercity bus network study (KFH Group 2010) chose five transit-dependent population characteristics to profile persons who rely on transit. Potential intercity bus needs were identified by comparing the locations served by the current network with the locations in Minnesota that have concentrations of persons more likely to rely on public transportation. The limitation with the Minnesota study is that characteristics of transit-dependent populations, which are mainly determined by urban public transit riders, could differ from intercity bus rider characteristics. This means that using transit-dependent population characteristics to determine areas of high intercity bus needs could introduce some bias. Also, identifying locations with high intercity bus need is not enough to evaluate an intercity bus network; how well the network connects to the destinations also should be studied. This paper extends the Minnesota study by comparing the characteristics of Tennessee rural-urban intercity bus riders to the characteristics of general travelers to obtain specific characterizations of potential riders.

Intercity Bus Riders Characteristics

A 1981 Tennessee intercity bus study (J. R. Wilburn and Associates 1981) developed a survey to ascertain a profile of passengers. It was conducted for a 24-hour period at several bus terminal locations. The survey results showed that a typical intercity bus passenger is age 16–25, uses the bus once a year to visit friend and relatives, travels over 10 miles by auto to get to and from the terminals, and come from households with total income of $7,501–$15,000 per year, which was lower than the 1981 national median household income of $18,033. Findings indicated some variance in automobile ownership between cities. In Chattanooga, Memphis, and Nashville, most respondents indicated that they owned one automobile, while in Jackson and Knoxville, most respondents indicated that they did not own an automobile.

The Bureau of Transportation Statistics (BTS) 1995 rider study (Bureau of Transportation Statistics 1997) concluded that intercity bus riders are more likely to be persons ages 65 years and older, female, minority, and less educated, who live in households with low income and no personal use vehicle available. Although the BTS study provides a good description of long distance intercity bus rider characteristics, the study parallels the scope of the ATS, focusing on people who travel more than 100 miles.

Although these two studies have given a comprehensive view of intercity travel mode choice modeling and intercity bus rider characteristics, both are obsolete, and there is a gap in the literature on within-state long distance bus traveler characteristics, particularly trips linking rural areas with urban centers. Therefore, it is crucial to obtain information about intrastate long-distance travelers in order to determine their characteristics and identify the areas of potential demand. This paper addresses this gap and evaluates how rural-urban intercity bus rider population demographics are different from overall intercity traveling populations.

In addition to identifying high intercity bus demand areas and assessing the connectivity of current network to those areas, methods to evaluate the connections of riders to destinations are introduced using a Geographic Information System (GIS) framework. This study proposes a framework to evaluate existing intercity bus network effectiveness at connecting probable intercity bus riders to destinations and introduces ways to improve these connections. Although this study observes only Tennessee rural-urban intercity trips and determined most to be less than 100 miles, it is reasonable to assume, because of similar state geography, that other states also have many intercity trips that are less than 100 miles.

Survey Methods

To gather information from intercity bus users, a questionnaire was developed for riders of each intercity bus route supported by the FTA 5311(f) program that funds fixed-route intercity bus service. This group included 5 rural transit companies (3 human resource agencies and 2 private service providers) that provide 756 route-miles of service in Tennessee. The surveys were conducted between May 1 and August 21, 2010. Intercity bus passengers were asked about their trips and to provide personal information. The survey explored trip and demographic characteristics.

Two survey methodologies were used. First, passengers are approached and interviewed by surveyors at different bus stops or onboard. This type of survey has a high response rate, a high quality of data collected, and allows surveyors to collect open-ended observations from riders. However, a considerable drawback of this method is that it has high cost for interviewers, owing to low bus service frequency, dispersed bus stop locations, and relatively few riders. A pilot intercept survey was performed to test the method. During the two-day pilot, 27 riders were interviewed.

Another survey method distributed questionnaires to bus riders with the help of the driver. Survey packages were distributed to the transit agencies, and drivers gave the surveys to boarding riders along with a pencil and mail-back envelope. This survey method had a relatively low response rate, but it greatly increased the cost-effectiveness of the data collection. Using this method, 446 questionnaires were sent out and 92 were returned (21% response rate). The true response rate is somewhat uncertain because we were unable to confirm that all surveys were actually distributed to passengers. Also, because of lack of supervision, some surveys were returned incomplete.

Survey Analysis and Comparison Results

Considering the low number of intercity bus trips recorded in the 2009 NHTS (i.e., nationwide, only 48 trips made by intercity bus out of 62,968 trips of greater than 30 miles), it is difficult to model intercity bus travel from this dataset. Indeed, the NHTS does not record any trips in Tennessee made by intercity bus, making it impossible to follow traditional mode-choice modeling strategies. Therefore, we adopted an alternative approach to estimate potential intercity bus rider demand. The data for all intercity trips made in Tennessee by all modes were extracted from NHTS. We supplemented the NHTS data with our on-board survey data. Comparing data in our survey to the dataset extracted from NHTS illustrates the diverging characteristics of intercity bus riders and their trips from car-based transportation. Furthermore, intercity bus rider attributes can serve as a reference to determine the number of potential intercity bus riders in each census tract in Tennessee; this was converted to estimate likely intercity bus rider population densities. Identifying these areas of population density helped to determine the areas with higher potential intercity bus demand.

The characteristics of intercity bus riders and trips were summarized from the survey responses and compared with those of intercity car trips of the same range of travel distance, extracted from the 2010 NHTS. For our survey, recorded trip lengths range from 6 miles to 162.5 miles (2 trips were recorded at less than 30 miles, which may be the result of misunderstanding the survey questions or a writing error). We defined the shortest length of an intercity trip as 30 miles, while the upper limit was rounded to 170 miles. The intercity bus trip distance includes distance from rider origin to boarding bus stop, travel distance on the bus, and distance from alighting stop to destination. A geographic criterion was used to filter the data from NHTS so that only trips made within Tennessee were selected. This was done to ensure consistency with the scope and administrative boundaries of the study. Because the trip origin and destination are unknown in the NHTS data, the state in which a survey responder's household is located was adopted as an alternative means to select the trips made in Tennessee.

The filtered NHTS dataset included 1,116 intercity trips distributed among all modes in Tennessee. Figure 1 shows that 1,075 trips were made by non-public transportation and no trips were made by intercity bus. Of these trips, 129 were made by private vans, which could include commuter vanpools.

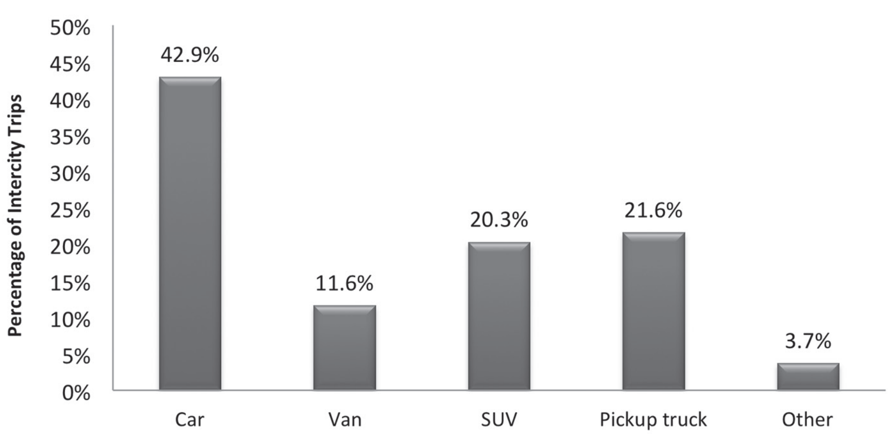

Figure 1. Transportation Mode Choice Percentage of NHTS Intercity Trips

In addition to transportation mode choice, 11 trip and rider characteristics were compared, including race, gender, age, employment status, ability to drive, household annual income, household size, number of vehicles available in household, education level, trip purpose, and trip distance. We assumed that these 11 characteristics influence a traveler's mode choice and, therefore, are included in both the NHTS and our survey.

Comparing the NHTS intercity trips (mostly car) in Tennessee with our dataset revealed significant differences in all variables with the exception of gender, shown in Table 1.

Table 1. Demographic Comparison between NHTS and Intercity Bus Trips

Variable Name	Category	NHTS Percentage	Survey Percentage	P-value
Race	White	94	86	0.0079
Sex	Male	56	53	0.6357
Employment status	Employed	63	46	0.0014
Capability to drive	Able	97	91	0.0036
Household income	Under $15,000	12	49	<0.0001
	$15,000-$27,499	9	20	
	$27,500-$52,499	27	8	
	$52,500-$89,999	32	8	
	$90,000 and over	20	14	
Household size	1	6	31	<0.0001
	2	50	28	
	3	17	9	
	4	18	16	
	5	6	8	
	6	2	0	
	7 and more	2	9	
Household vehicle	0	0	1	<0.0001
Count	1	9	40	
	2	37	30	
	3	34	22	
	4	11	7	
	5 and more	9	1	

Table 1. Demographic Comparison between NHTS and Intercity Bus Trips (cont'd.)

Variable Name	Category	NHTS Percentage	Survey Percentage	P-value
Education level	Less than high school	7	7	0.0009
	High school or GED	32	10	
	Some college or vocational degree	32	39	
	Bachelor's degree	16	31	
	Graduate or professional degree	13	7	
Age	Below 15 yrs	4	0	0.0122
	15–24 yrs	6	14	
	25–34 yrs	10	13	
	35–44 yrs	17	9	
	45–54 yrs	20	21	
	55–64 yrs	22	27	
	Equal to or above 65 yrs	21	15	
Trip purpose	Work/school	27	24	<0.0001
	Religious activity	4	2	
	Medical/dental services	4	39	
	Shopping/errands	20	1	
	Social/recreational/family/personal business	14	10	
Trip length (miles)	Mean value	53.8	75.5	<0.0001

Note: All p-values were estimated using the Chi Squared test with the exception of trip length, evaluated with Wilcoxon Rank Sum test.

The results obtained were different from those observed in other studies, which demonstrates the importance of performing this comparison. Key results are summarized as follows:

1. Although age differences between private vehicle users and intercity bus riders are significantly different, there was no special trend to characterize the ages of intercity bus riders.
2. The race of intercity bus riders was more likely to be non-white.
3. Intercity bus riders were more likely to be unemployed.
4. Intercity bus riders were more likely to be unable to drive.
5. Intercity bus riders were more likely to be from low-income households.

Nearly 70 percent of intercity bus riders' annual household incomes were under $27,499, compared to 21 percent of non-riders.

6. Intercity bus riders were more likely to either live alone or have greater numbers of household members, often seven or more persons in a household.
7. Intercity bus riders were more likely to have one or fewer vehicles in the household, although there were very few zero-vehicle households in either survey. This, combined with the high number of people per household, results in higher reliance on transit service.
8. Intercity bus riders in our sample were likely to take trips for medical purposes. This could be the effect of a bias in the sampling approach, i.e., many of the bus services we surveyed fed regional medical centers.
9. Intercity bus trips were longer in distance than intercity trips by other modes.

The characteristics of intercity bus riders discovered from this survey were, to a large extent, consistent with the findings of BTS intercity bus rider study: minority, less educated, low income, and low number of personal vehicles. But they also they differed in some ways: the BTS study pointed out that most intercity bus riders are more likely to be 65 or older, while this study found no special trend on the age. This study found riders are more likely unemployed, unable to drive, live alone, or have a large household. Our study found that intercity bus rider characteristics differ compared to other studies. Different time periods, locations in which the studies were conducted, goals of intercity bus projects, and many other factors could contribute to the difference of characteristics. When system planners try to determine a demographic profile of local rider, it is important to assess local demand profiles through surveys rather than adopting the profile from other studies.

Geographic Network Analysis

The data from the on-board survey were used to profile typical intercity bus riders, focusing on characteristics we can observe in census and American Community Survey (ACS) data to identify high-demand census tracts. Five metrics were quantified for each census tract in Tennessee: non-white population density, unemployed population density, poverty-level household density, large-size household density, and low vehicle count household density. Census tracts were ranked on the five metrics. For example, the first ranking is given by non-white density—the higher the non-white population density, the higher the census tract's ranking. The five rankings were summed to get a total ranking for each census tract.

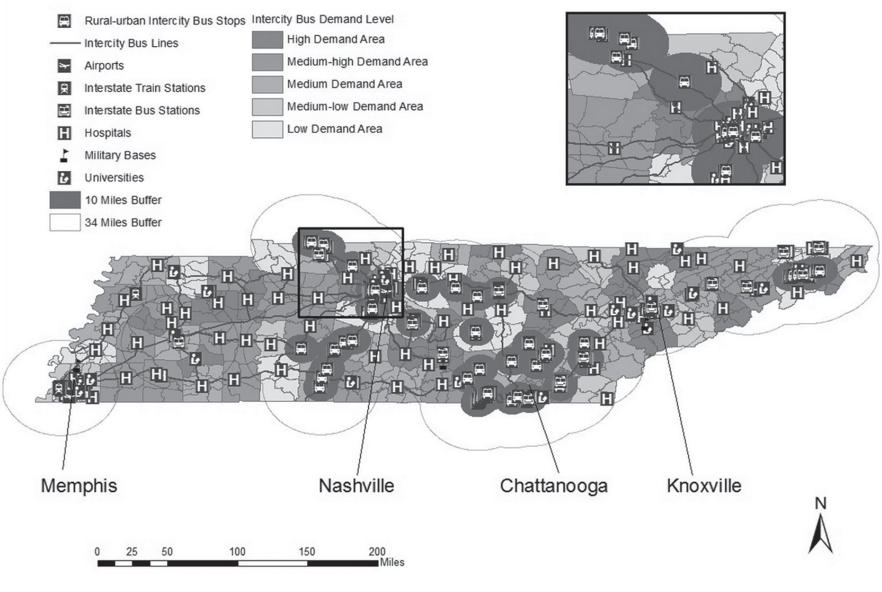

Figure 2. Tennessee Intercity Bus Demand and Meaningful Destinations Map

The intercity bus demand was divided into five levels using Natural Breaks (Jenks) algorithm: high, medium-high, medium, medium-low, and low (based on demographic rankings). The level boundaries were set where there were relatively big jumps in the rankings so as to maximize the differences between classes. This grouping level could change depending on analysis purpose or policy goal of intercity bus service coverage. Out of 1,261 census tracts, 228 were identified as the high intercity bus demand area with a total area of 7,684 square miles and 973,795 residents, approximately 18 percent of Tennessee's area and 16 percent of its population. The next highest category, medium-high demand areas, includes 296 census tracts with an area of 12,254 square miles and 1,362,653 people, which is about 29 percent of Tennessee's area and 22 percent of its population. Figure 2 shows that census tracts with similar demand levels usually are located adjacent to each other, creating the potential for intercity bus corridors.

Rider and Destination Connectivity Analysis

Six agencies provide fixed-route scheduled rural-urban intercity bus services within Tennessee, serving 87 stops. The access shed to these stops, defined as the access and egress distance, was summarized based on our survey dataset. The mean

Euclidean access distance was 10.1 miles and the maximum was 34.0 miles. For the egress distance, almost all trips were destined for location of the bus stop (usually a major trip generator), with a mean distance of 1.2 miles and 90 percentile distance of 9.2 miles. Average egress distance was shorter than access distance because some intercity bus agencies provide stop-to-door service, transporting passengers directly to the destinations. While it is not likely that passenger origin is exactly at the starting stop, in most cases, their destination was at one of the ending stops. In these cases, their egress distance was zero.

To evaluate how well bus stops connect to riders, two buffers were made around each bus stop, one with a radius of the mean access distance value, 10 miles, and the other with a radius of the maximum value, 34 miles, as shown in Figure 2. Considering that 34 miles was the greatest distance we observed from the origin to boarding stop, the aim of the buffer with this radius was to cover all of the high and medium-high demand areas in Tennessee; the 10-mile radius buffer was meant to cover the high demand area alone.

Combining the buffers with the demographic distribution, 1,222 square miles of the 7,684 square mile high demand areas (around 16%) were covered by the small buffer while 9,875 square miles of the 19,938 square mile medium-high and high demand areas (50%) were covered by the large buffer. Looking at Figure 2 another way, the total area of the small buffer is 8,735 square miles, compared to 7,684 square miles of high demand area; the small buffer covers some relatively low demand areas. Similarly, the total area of the large buffer is 33,618 square miles, compared to 19,938 square miles of high and medium-high demand areas. This may imply that the bus stops are not well located to cover the high and medium-high demand areas.

Bus stops are designed to connect to riders to activity centers. Because origins and destinations often are not located in areas with high numbers of people who match intercity bus rider demographics, we determined how well these stops connect to activity centers in order to evaluate the most useful location of bus stops. One of the weaknesses of using NHTS data is that destination data are unavailable for car trips. We relied on destination information from our surveys, which was closely aligned with existing bus rider trip characteristics. This is a potential weakness since our survey was based on existing riders who are served by existing destinations, creating potential bias in our sample (i.e., we did not sample individuals whose destinations were not served by existing intercity bus). Depending on the purpose of an intercity bus program, the destination stops should connect to a variety of places such as hospitals, colleges and universities, airports, military bases, large employers, and so on. The Tennessee intercity bus pilot program was aimed at connecting people from rural community to urban activity centers, not specifically targeting commuting trips. We focused on medical service, urban transit centers, educational opportunities, and military bases. In the context of this study, hospitals, universities, airports, interstate bus and train stations, and military bases were regarded as meaningful destinations (see Figure 2). More specific destination studies could be warranted, depending on specific goals of the intercity bus program (e.g., displacing car trips versus providing better service to areas with unmet demand).

An intercity bus stop is considered connecting to a meaningful destination when it is located within 10 miles of the destination because it is approximately the 90th percentile egress distance. It is also consistent with KFH Group study (KFH Group 2010). All the airports, interstate bus and train stations, hospitals, military bases, and universities in Tennessee were inventoried for this study: there are 4 commercial airports, 16 interstate bus stations, 2 interstate train stations, 156 hospitals, 3 military bases, and 67 universities and research institutes. Spatial analysis was used to determine how many stops are within the 10-mile buffer of these meaningful destinations. We found that 8 stops connect to airports, 35 stops connect to interstate bus stations, 0 stops connect to interstate train stations, 70 stops connect to hospitals, 0 stops connect to military bases, and 49 stops connect to universities and research institutes. Some of the stops connect to two or more destinations. Seventy-two stops (83%) connect to the identified meaningful destinations, indicating the bus stops are well connected to the destinations.

In summary, intercity bus service struggles to provide service in a many-to-few origin and destination geography. Many potential origins are underserved, though the few key trip generators seem to be adequately served. To improve the existing intercity bus system, stop locations should be rearranged to better connect to the high-demand residential areas. About 15 percent of stops were found neither within high or medium-high demand areas, nor connected to any meaningful destinations. One possible improvement would be to relocate those stops to the identified high and medium-high demand areas. Some recent approaches to providing flexible deviated fixed-route service hold promise to maintain scheduled service on fixed routes while serving dispersed origins and destinations (Nourbakhsh and Ouyang 2012).

Conclusions

Intercity bus rider characteristics and trip characteristics are different from car-based intercity or interstate trips. To evaluate these differences, we performed an onboard survey to measure Tennessee intercity bus rider characteristics and compared them with NHTS data on intercity travel. Rider characteristics were obtained from the survey and compared to previous studies. The comparison confirmed that intercity bus riders are usually non-white, less educated, and low income and have low number of personal vehicles. It also revealed that the characteristics differ between other studies, making it necessary for planners to gather information on local riders to develop regional rider profiles rather than relying on characteristics from other studies.

This research provides a new approach to identifying high intercity bus demand areas, evaluating the current and future intercity bus networks as this service continues to grow. It also introduces ways to identify the bus stops that do not have good connectivity to either origins or destinations and criteria to relocate them. The dataset used in this study is publicly available, with the exception of the intercity bus rider onboard survey data. Using the framework presented here, state transportation planners and public and private transit operators can use available data to profile areas where intercity transit could be supported by adequate ridership and identify existing intercity bus service gaps to ultimately improve the cost-effectiveness of the service. Similar studies can be performed in different contexts. In those cases, local parameters should be calibrated under the proposed framework. Access mode is a key consideration and determines the coverage radius of intercity bus stops. We used a method that usually relies on auto-access to origins and walk or transit access to destinations. Based on different goals of rural-urban bus service, a unique inventory of meaningful connections should be developed. Policy coverage areas should be set based on goals of study or pre-set constraints, such as only 10 percent of the area could be regarded as high-demand area or intercity transit should cover 90 percent of high demand areas.

This paper has several limitations. First, because intercity bus service and ridership are low in Tennessee, data volume and quality presented challenges in developing robust transportation demand models. The data collection method possibly introduces some self-selection bias—that is, we surveyed existing bus riders on existing routes and projected those characteristics in the demand analysis. Nonetheless, this paper proposes one of the first contemporary frameworks to evaluate the demand and network connectivity of existing intercity bus networks to potential riders and destinations and has begun to address a research gap on a mode of transportation that is beginning to grow after decades of decline.

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References

Ashiabor, S., H. Baik, and A. Trani. 2007. Logit models for forecasting nationwide intercity travel demand in the United States. *Transportation Research Record: Journal of the Transportation Research Board* 2007: 1-12.

Bureau of Transportation Statistics, U.S. Department of Transportation. 1997. U.S. Profile--American Travel Survey. Washington D.C.: Research and Innovative Technology Administration.

Fravel, Frederic D., National Research Council. 2011. Toolkit for estimating demand for rural intercity bus service, TCRP report 147. Transportation Research Board, Transit Cooperative Research Program. Federal Transit Administration, and Transit Development Corporation. Washington, DC: Transportation Research Board.

J. R. Wilburn and Associates, Inc. 1981. Tennessee intercity bus study. Tennessee Department of Transportation.

KFH Group, Inc. 2010. Minnesota intercity bus network study. Minnesota Department of Transportation.

Koppelman, Frank. 1989. Multidimensional model system for intercity travel choice behavior. *Transportation Research Record: Journal of the Transportation Research Board* 1241: 1-8.

Morrison, Steven, and Clifford Winston. 1985. An econometric analysis of the demand for intercity passenger transportation. *Research in Transportation Economics* 2: 213-237.

Nourbakhsh, Seyed Mohammad, and Yanfeng Ouyang. 2012. A structured flexible transit system for low demand areas. *Transportation Research Part B: Methodological* 46(1): 204-216.

Schwieterman, Joseph P., and Lauren Fischer. 2010. The intercity bus: America's fastest growing transportation mode: 2010 update on scheduled bus service. Chaddick Institute for Metropolitan Development, DePaul University.

Schwieterman, Joseph P., Lauren Fischer, Sara Smith, and Christine Towles. 2007. The return of the intercity bus: The decline and recovery of scheduled service to American cities, 1960-2007. Chicago: School of Public Service Policy Study, DePaul University, Chaddick Institute for Metropolitan Development.

Stopher, Peter R., and Joseph Prashker. 1976. Intercity passenger forecasting: The use of current travel forecasting procedures. Paper presented at Annual Meeting of the Transportation Research Forum.

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Intercity Bus Service Funding and Assessment Methodology

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Abstract

The Federal Transit Administration (FTA)'s 5311(f) program requires that 15 percent of 5311 program funds given to a state be used to develop and support intercity bus (ICB) service. This 15 percent can be waived if the governor certifies that the ICB needs are being met within the state. This certification became harder to justify when FTA began requiring a more stringent consultation process before certification could be given. The objectives of this study are to learn about current practices of ICB service funding mechanisms, funds prioritization, and determination processes and strategies that promote ICB service. An assessment methodology for Montana was developed to determine whether ICB needs are being adequately met and how to allocate funds to support service. The results of this study will be valuable to other states considering developing methodologies for certification and funding allocation purposes.

Introduction

The Federal Transit Administration (FTA) defines intercity bus (ICB) service as:

> regularly scheduled bus service for the general public that operates with limited stops over fixed routes connecting two or more urban areas not in close proximity, that has the capacity for transporting baggage carried by passengers, and that makes meaningful connections with scheduled nter-city bus service to more distant points, if such service is available (FTA 2007).

Due to deregulation of ICB, an increase in personal automobile ownership, competition from airlines and Amtrak, and high operating costs, the ICB industry abandoned numerous unprofitable routes across the United States in the last five decades, leaving nearly 15,000 communities disconnected. ICB operations, however, have been recovering since 2006. The increase is related to federal transit laws, particularly Title 49 United States Code 5311(f), which support the development and revitalization of ICB transportation (FTA 2007). ICB service funding from FTA's Section 5311(f) program (Non-Urbanized Intercity Bus Formula Program) is a part of a larger program known as Formula Grants for Other than Urbanized Areas. The 5311 program provides state funding to support public transportation in areas with populations less than 50,000. Goals of the program include:

1) enhancing the access of non-urbanized populations to health care, shopping, education, employment, public services, and recreation
2) assisting in the maintenance, development, improvement, and use of public transportation in non-urbanized areas
3) coordinating programs and services to facilitate the most efficient use of passenger service transportation funds in non-urbanized areas
4) assisting in the development and support of intercity bus transportation
5) providing for the participation of private transportation providers in non-urbanized transportation (FTA 2010)

The 5311(f) program requires that 15 percent of the total 5311 program funds given to a state be used to "carry out a program to develop and support intercity bus transportation" (FTA 2007). This 15 percent can be used elsewhere if the governor certifies that the ICB needs are being met within the state. Prior to the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) of 2005, governors often certified that their ICB needs were being met in order to use the funds in other areas. This certification became harder to justify after SAFETEA-LU because it required a more stringent consultation process before certification could be given. Hence, it is critical for states to develop assessment methodologies that can be used periodically to determine whether or not ICB needs are being adequately met and how to allocate funds to support ICB service. Moreover, it is important to learn about state funding practices in response to the 5311(f) program, which can be valuable for promoting ICB services in non-urbanized areas.

This study explored the mechanisms of ICB funding currently used by states. After a literature review was conducted, a survey to Departments of Transportation (DOTs) in selected rural states was carried out to further explore ICB funding mechanisms, funds prioritization, and determination processes, the proportion of 5311 funds used for ICB services, and strategies to promote ICB services. An assessment methodology for ICB service needs was developed for the rural state of Montana. This methodology can be periodically used to determine whether or not ICB service needs are being adequately met. The results of this study will be valuable to other states considering developing their own methodologies for certification and funding allocation purposes.

Review of Intercity Bus Service Funding

There are two primary methods for funding ICB service. The first is a grant funding process, which involves ICB providers applying for funding and state DOT personnel determining which applicants receive it. Iowa uses this method with the following priority rankings:

1) providing existing ICB service (award $0.20/mile)
2) adding new feeder routes from non-urban communities (award $0.50/mile for new service, $0.20/mile for duplicate routes)
3) increasing public awareness and marketing (award case-by-case)
4) upgrading equipment and facilities such as ADA accessibility equipment (award case-by-case) (Lindly 2009)

Colorado, Minnesota, and Pennsylvania DOT programs also provide assistance in the form of grants to eligible applicants (KFH Group 2010).

A different approach to ICB service funding is a system that more closely resembles a bid process. State DOT personnel identify potential ICB service routes in need of upgrades, then issue a request to qualified bidders. The bidders propose a compensation rate for providing services on the identified routes. Washington State DOT (WSDOT) uses the bid method. After WSDOT staff identifies a route in need of service, they issue a Request for Proposal (RFP) and ask that bidders provide their qualifications, price, and experience and a proposed business plan. The bids are reviewed by a panel consisting of WSDOT staff, a Washington Utilities and Transportation Commission (WUTC) representative, local (non-bidding) transit operators, and representatives of the non-bidding private bus industry (KFH Group 2007).

Other states, such as California and Oregon, are not limited to one funding approach. Caltrans provides ICB assistance with grants, RFPs, and a mixture of both approaches. In Oregon, funding is provided through a grant under the discretionary program, while an RFP approach is used under a pilot project for service on particular corridors that were identified by an Oregon DOT needs study (KFH Group 2010).

ICB service funds are used for different purposes depending on an individual state's funding priorities, as noted in its ICB plans. Aside from the 5311(f) program, a number of states have their own funds for subsidizing ICB services (KFH Group 2002). State funds allow more flexibility in funding projects than is possible with the federal program and its rules and regulations. Many local funds are used by intercity program sponsors to support ICB services (KFH 2002). In general, however, state and local funds are used as the "local match" that is required under the 5311(f) program.

State of the Practice in ICB Service Funding

A survey was distributed to DOT public transportation directors in 10 states—Colorado, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming—to learn about current funding practices. These states were selected in consultation with the Montana Department of Transportation and were selected based on their rural nature and other similarities to Montana. Nine of these 10 state officials responded to the survey (a 90% response rate). Survey results of funding practices in the nine states that responded are summarized in Table 1.

When the states were asked about their current use of ICB funds, six of the nine respondents reported that their states used 15 percent of the 5311(f) for ICB service as directed by federal statute. Wyoming stated it used 20 percent of its 5311(f) for ICB service in FY 2011. Wyoming's practice had been to set aside 15 percent of 5311(f) for ICB service; however, from 2006 to 2010, there was a lack of sufficient projects to use the full amount allocated for this use. In addition, Wyoming allocated funds to rural feeder services and a regional commercial bus service (capital funds). Colorado has steadily increased its 5311(f) percentage from 6 percent to 14.8 percent in the past 6 years. South Dakota certified that ICB service needs were being met and used a portion of the 15 percent toward ICB service. The exact percentage used was unclear, but approximately 4 percent was reported to be allocated to "ICB provider(s)."

Table 1. Summary of Funding Practices in Rural States

State	Proportion of 5311 Funds [a]	ICB Funding Mechanism	ICB Funds Prioritization and Determination Process
Colorado	14.8%	Grantor/ grantee system	Funding allocation based on a statewide and regional ICB study. *Process:* a) ICB providers submit proposals. b) ICB Advisory Committee reviews and scores applications. c) CDOT Division of Transit and Rail determines which projects to fund and at what level.
New Mexico	15%	N/A	N/A
North Dakota	15%	Grantor/ grantee system	2011 is NDDOT's first year using ICB grant application process. Funding allocation prioritized based on identified routes and needs listed by providers.
Oregon	15%	Both (grantor/grantee and RFP/bid systems)	15% as required by FTA formula. *Process:* a) Discretionary Grant Program; b) contract ICB service based on service gap analysis; c) Transit Information Investments based on information gaps.
South Dakota	4%*	Grantor/ grantee system	ICB provider included in yearly reviews for what projects can be funded at what amounts. Process: a) ICB providers submit budget requests; b) SDDOT reviews budget requests; c) determinations made.
Texas	15%	Grantor/ grantee system	15% as required by FTA formula. Process: a) Submitted proposals scored by interagency team, funding amounts recommended; b) funds awarded by Texas Transportation Commission.
Utah	15%	RFP/bid system	15% as required by FTA formula if sufficient projects available. Funding allocation based on previous ICB study that identified areas for ICB service.
Washington	15%	RFP/bid system	15% as required by FTA formula. Funding allocation based on analysis of 2007 Statewide Rural Intercity Bus Plan. *Process:* a) Review of state demographics to identify areas with mobility needs; b) based on demographic analysis, routes to towns where connections to national intercity network can be made are identified and prioritized for funding.
Wyoming	20%	N/A	N/A

** South Dakota noted that they also fund rural feeder services and "Jefferson Lines" for an amount that was not specified in the response.*

While the previous question asked about current funding practices, the next question asked states to describe the process used to determine the amount of funds allocated to ICB service. Three states (Texas, Washington, and Oregon) reported they used 15 percent of 5311(f) for ICB as required by the FTA formula, while Utah DOT stated it used 15 percent assuming sufficient projects/services were available to use the funds. In South Dakota and Colorado, ICB providers first submitted applications (budget requests) that were reviewed to determine which projects to fund. Colorado used an ICB Advisory Committee comprising members from the Transit and Rail Division, the Regional Transportation District, and the Colorado Public Utilities Commission to review and score applications, which were then considered for funding based on the scoring results. North Dakota implemented its ICB grant application process beginning in FY 2011. Prior to that, it used historical data and the judgment of a solitary transit-focused DOT employee to decide which projects to fund. Two other states (New Mexico and Wyoming) did not respond to this question.

The survey asked a question concerning prioritization of funding allocations. Three states (Utah, Colorado, and Washington) reported that they prioritized the funding based on results from statewide and regional ICB studies. Utah indicated it funded a shared route with Colorado, and the remaining funding was allocated based on an RFP and a recent statewide ICB study that identified areas for ICB service. In Washington, mobility needs were first identified using demographics, then routes were identified with towns where connections to the national intercity network could be made. Colorado indicated a preference to continue funding existing routes before initiating new routes. Texas DOT used an "interagency team" to review and score submitted proposals and prioritize funding. Oregon funded projects first through a Discretionary Grant Program, then provided ICB funds based on a "service gap analysis" and provided transit information investments based on identified "information gaps." South Dakota reported that its presumably sole "ICB provider" was involved in yearly reviews to help prioritize allocation of funds. North Dakota stated it prioritized funding based on routes and needs prioritized by ICB providers. Two states did not respond.

The states were asked a question regarding how they awarded funds to potential ICB providers. Options included "a grantor/grantee system with potential services applied for similar to a grant" or "an RFP/bid system with potential projects identified by the DOT, then issuing an RFP on which service providers then bid," or "a different system." Results showed that four states (Colorado, North Dakota, South Dakota and Texas) used a grant-type system and two states (Utah and Washington) used an RFP/bid system. Oregon reported that both processes were used. Two states did not respond.

Promoting ICB Service

In the survey, the states were asked if any state agency actively promoted ICB service. Seven of the nine states responded to the question, with six states reporting that they did actively promote ICB services. Colorado noted that it frequently issues press releases on new ICB routes, stations, schedules, equipment, and other information. It also pays for newspaper advertising of routes and schedules and is currently developing a transit map that will include ICB service. Washington "promotes ICB service at conferences, both regionally and nationally" and also contractually expects the ICB providers to maintain websites and advertise through radio, television, and newspaper media. Washington also offers online ticketing and reservation capabilities. Other states said their actions were minimal but included website information with routes and schedules. Information about the strategies used to promote ICB service is summarized in Table 2. Colorado and Washington indicate that ICB ridership in their states has increased in the last two years.

Table 2. Summary of Strategies in Promoting ICB Service

State	Strategies in Promoting ICB Services
Colorado	a) Frequently issues press releases on new ICB information. b) Pays for newspaper advertising of routes and schedules. c) Is currently developing a transit map.
North Dakota	First year (2011) in promoting ICB service.
Oregon	a) Has both printed and electronic ICB service schedules. b) Maintains websites, including Trip Check-TO transit information (http://www.tripcheck.com/rtp-to/cityCounty/cityCountySearch .aspx) and Oregon-POINT service (www.oregon-point.com).
South Dakota	a) Has press releases when a new rural transit provider may become a feeder service. b) Supports websites.
Texas	Marketing is an eligible expense for project funded through 5311(f).
Utah	Does not actively promote ICB services.
Washington	a) Promotes ICB service at regional and national conferences. b) Promotes programs through cooperative assistance (providing documents) to other states. c) Each ICB route is named after products produced in the particular part of the state (e.g., Gold Line, Grape Line, Apple Line).

Assessment of Intercity Bus Service Needs in Montana

Although many states have their own ICB funding prioritization process, there is still a lack of information on the development of assessment methodologies that can be used to periodically determine whether or not ICB needs are being adequately met and how to allocate funds to support ICB service. Montana was used to develop a methodology for the assessment of ICB service needs and funding allocation.

Assessment Methodology

As a rural state, national/major ICB services in Montana are provided in the areas along Interstates 90 and 15 and US Highway 93 north of Missoula. A large geographic area of the state does not have ICB services. An analysis indicates that approximately 45 percent of Montanans (436,799 people) live in cities served by national/major ICB services, including 8 of the 10 largest cities in the state, as shown in Table 3. Only three cities in Montana exceed this threshold and are considered urban: Billings, Missoula, and Great Falls (U.S. Census Bureau 2009).

Based on existing ICB funding practices in Montana and other rural states, a method combining an annual process and a triennial consultation process was developed, as shown in Figure 1. The process includes five components: review of existing ICB services, support for existing services, determination of funding, analysis of potential new services, and funding for new services. The first three steps are used as an annual process to support existing ICB services, and the triennial process is to determine funding for new services.

Annual Process

The proposed annual process begins with review and evaluation of the performance of existing ICB services in order to assess to what degree the ICB projects have achieved their goals. The Montana Department of Transportation (MDT) reviews existing public transportation services within the state through the use of information obtained in quarterly reports submitted by providers. The current review analyzes factors including ridership, mileage, and the capital needs of the ICB providers.

Based on review results, decisions regarding support for existing services fall into two categories: 1) services to be cut or to receive reduced funding, and 2) services to receive level or increased funding. Services that have decreasing ridership may receive reduced funding in the next fiscal year or could be completely cut, depending upon ridership levels. Alternatively, services with increasing ridership may receive additional funding from MDT. It is recommended that MDT continues to use its current evaluation practices for these initial steps.

Table 3. Cities/Towns with ICB Service in Montana[a]

City/Town	2009 Population [b]		City/Town	2009 Population	
	Estimate	*Rank* [c]		*Estimate*	*Rank*
Billings	105,845	1	Columbus	2,039	34
Missoula	68,876	2	Ronan	1,999	36
Great Falls	59,366	3	Three Forks	1,970	37
Bozeman	39,282	4	Forsyth	1,865	39
Butte-Silver Bow	32,268	5	Big Timber	1,740	41
Helena	29,939	6	Manhattan	1,677	43
Kalispell	21,640	7	W. Yellowstone	1,502	46
Whitefish	8,400	10	Boulder	1,475	47
Belgrade	8,192	11	Whitehall	1,191	52
Miles City	8,123	12	St. Ignatius	807	65
Livingston	7,380	13	Cascade	770	67
Laurel	6,750	14	Bridger	736	68
Polson	5,231	17	Terry	567	79
Glendive	4,628	20	Wibaux	480	82
Dillon	4,226	21	Drummond	322	94
Hardin	3,532	22	Hysham	233	100
Deer Lodge	3,517	24	Lima	231	101
Total Population with Service				436,799	

[a] *ICB Service, for this purpose, is defined as listed stops on websites of regional bus service providers Greyhound, Rimrock Stages/Trailways and Salt Lake City Express.*

[b] *Montana 2009 population estimate 974,989.*

[c] *Ranking based on 129 cities/towns recognized by U.S. Census.*

Source: (U.S. Census Bureau, 2009)

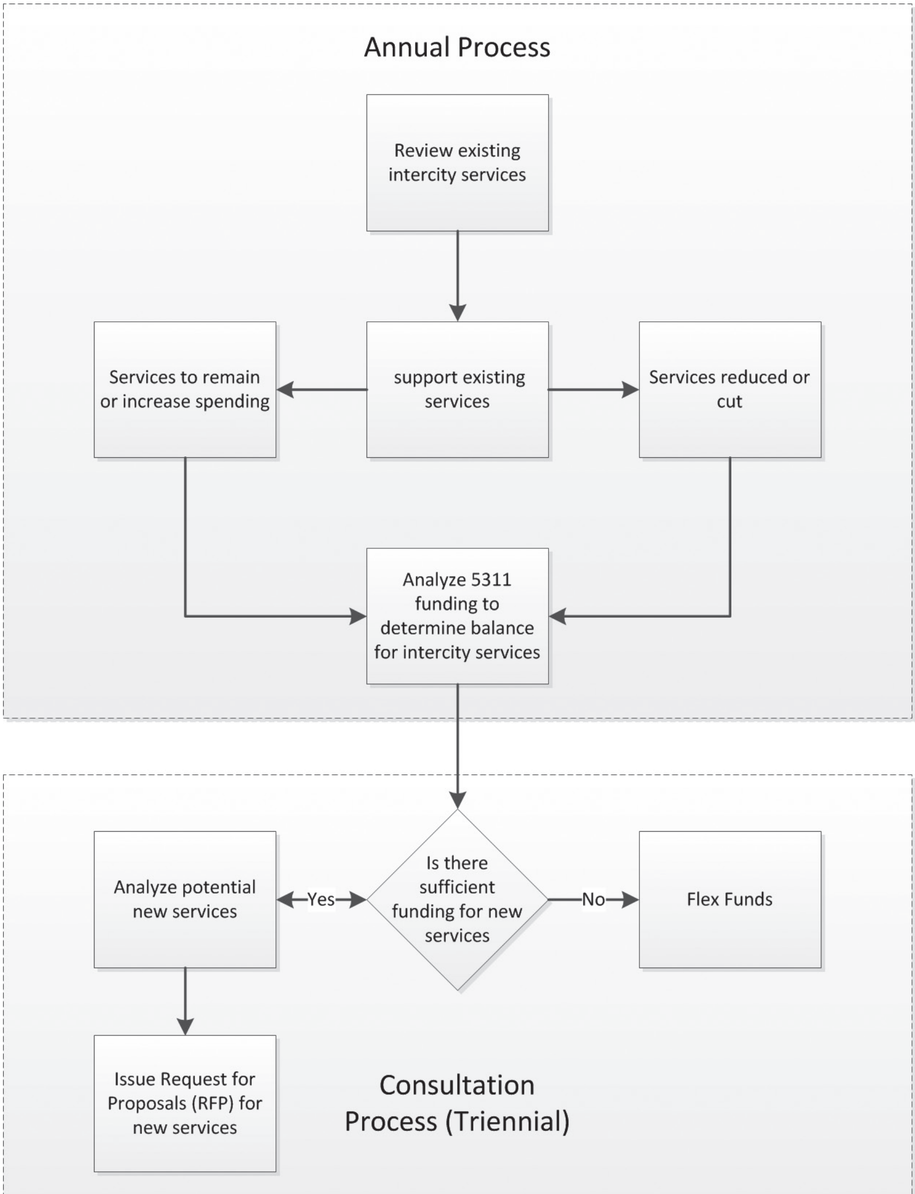

Figure 1. Assessment Methodology

The savings from those services that receive reduced funding or where funding is cut altogether are returned to the state's 5311(f) program fund. This is balanced by additional spending for those services that would receive increased funding for the next fiscal year. New ICB services may be proposed (new routes and/or frequency), which could be funded and, as a result, increase the amount of 5311(f) program funds to be spent. After reviewing the request, the State selects and determines the funding to support existing ICB services. The balance for ICB services is then determined based on the above savings and spending. It should be noted that while FTA guidance discusses a target amount for funding ICB services (15% of the funds), it does not preclude a state from spending more than 15% of its Section 5311 funding on ICB services.

Triennial Consultation Process

If there is sufficient funding in the 5311(f) program based on the annual process, the State goes through a triennial consultation process to determine which new services (routes), if any, to support. This could include funding new routes as well as restoring ICB services that were previously discontinued.

This process first determines whether any cities in Montana with a population of 10,000 or more do not have ICB service. The larger communities are the initial focus of an analysis. If all communities of this size have existing ICB service, an analysis of the next largest communities—population 5,000–9,999—is conducted, followed by an analysis of communities with a population between 2,000 and 4,999 to ascertain whether ICB services or "feeder service" connections to ICB services are available. It is noted that, based on the 2010 U.S. Census (CEIC 2011), Montana has 7 cities with a population of 10,000 or more people, 9 cities with a population between 5,000 and 10,000 people, and 15 cities with a population between 2,000 and 4,999 people. FTA allows funding of "feeder services" that connect small transit operations and ICB carriers. It is likely that any spending of 5311(f) funding in cities/towns with a population of less than 10,000 people would be for feeder services, which are not subject to the same regulations as other intercity bus services.

Once the initial review of Montana's largest cities is completed, a route analysis is undertaken. The purpose of the route analysis is to identify potential ridership on new or previously-cut routes. Surveys of the general public and local transit agencies can provide information on cities and city pairs that may be in need of ICB services. The list of cities and/or routes from the surveys can be used as a basis to further identify potential routes most in need of ICB services. The State may use different evaluation criteria to assess potential new service routes such as population (density), transit-dependent population, household income, and automobile ownership. Use of a simple evaluation tool to estimate ICB demand based on the populations of locations served is recommended to analyze potential new services. The Toolkit for Estimating Demand for Rural Intercity Bus Services (TCRP 2011) was developed through the Transit Cooperative Research Program (TCRP) program. The inputs for demand forecasting include state, locations (cities), and route length (one-way length in miles). The population will automatically generate for each of the cities selected in the toolkit. However, the toolkit uses population information based on the 2000 Census. With the 2010 Census data available, 2000 Census may not be accurate if there were significant demographic changes between 2000 and 2010 for the proposed route.

Once the route analysis is conducted, MDT consults with local and intercity transit providers to determine which routes would be the most likely to succeed (attract ridership). After the potential new services are identified and analyzed, the State decides on which new routes would be supported with new funding. To get the most service for the least cost, it is recommended that MDT use a Request for Bid (RFB) process. Once MDT has determined which route or routes will be funded, it issues an RFB and transit providers can bid to operate the new services.

Determination of Whether ICB Needs Are Being Met

As a result of the analysis and consultation process, the state may certify that ICB service needs are adequately being met if no new routes are identified that can provide service at a reasonable cost. It is recommended that MDT use a cost-per-ride and cost-per-mile analysis when determining whether or not to implement (and/or continue to support) ICB services, including feeder services. It is recommended that the threshold be set at the 85th percentile of costs for similar services. The 85th percentile is used as a basis for several recommendations herein. It is selected as a "reasonable" threshold and is based on the fact that the 85th percentile is used frequently for setting speed limits on many roadways. Therefore, if a new feeder service is planned, it should not be implemented if the projected cost per ride will be more than the cost per ride at the 85th percentile of existing feeder services in Montana.

While there may be requests for new services or routes, MDT could certify that the needs of the state are being met even if there are requests for new services. Montana is a rural and frontier state, with only 31 of its 129 cities and towns having a population of 2,000 or more. Due to low population densities, it is recommended that MDT focus support on towns and cities with a population of at least 2,000. At the time of this study, the only cities with a population between 2,000 and 4,999 that do not have ICB service are Colstrip and Red Lodge. This means that 94 percent of Montana's most-populated cities have either direct service from national or regional intercity carriers or feeder services to those carriers. It is recommended that a threshold of 85 percent of Montana's largest cities (currently 26 of 31 cities) be used as a determination of whether the needs are being met. If the state determines that the ICB needs of the state are being met, and fewer than 15 percent of the Section 5311(f) funds need to be expended, it can provide a partial certification.

As presented in the FTA's Circular 9040.1F (FTA 2007), if less than 15 percent of the 5311(f) funds will result in needs being adequately met, the State "may submit a "partial" certification for the reminder of the 15 percent and spend only the portion needed to ensure that the intercity bus needs are adequately met." As shown in Table 4, MDT has spent between 9 and 12.7 percent of its FTA Section 5311(f) funding on ICB services for each of the last four State fiscal years, and a partial certification is the most likely outcome in the future.

Table 4. 5311(f) Budget and Funding in Montana

State Fiscal Year	5311(f) Funds Available	5311(f) Obligations	Number of Agencies Funded
2008	$990,406	$880,955	14
2009	$1,068,791	$898,016	12
2010	$1,127,602	$802,510	8
2011	$1,126,539	$676,268	6
Total	$4,313,338	$3,217,749	

Concluding Remarks

The literature review and survey found that the prioritization and determination of funds for ICB projects/services include two approaches. States conducting ICB studies to identify routes were found to use an RFP/bid system to award funds. Second, for those states using a grantor/grantee system to award funds, the general process of determining funds included three steps: 1) submitting proposals by ICB providers, 2) reviewing and/or scoring applications, and 3) determining funds for projects.

The survey also revealed that most rural states have been promoting ICB services. The strategies included press releases on new ICB information, newspaper advertising of routes and schedules, development of transit maps, and cooperative assistance to others.

MDT has a process in place to review transit providers on an annual basis to determine funding levels for the subsequent fiscal year. This research study provided a process that can occur as a triennial process to determine if intercity bus service needs are being met and, if not, a process to determine where service should be implemented (providing sufficient funding exists). Currently, 29 of 31 of the largest cities in Montana have access to intercity bus service. If future analyses yield similar results, it is recommended that MDT use a partial certification so that unspent Section 5311(f) funds can be used for other public transit services.

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References

CEIC (Census and Economic Information Center), Montana Department of Commerce. 2011. Census 2010 - Census place population summary (City, Town, CDP). U.S. Census Bureau, Census 2010 PL 94-171.

Federal Transit Administration (FTA). 2007. FTA Circular 9040.1F. Federal Transit Administration, Washington, D.C.

Federal Transit Administration (FTA). 2010. Formula grants for other than urbanized areas (5311). Accessed July 6. http://www.fta.dot.gov/funding/grants/grants_financing_3555.html

KFH Group, Inc. 2002. Effective approaches to meeting rural intercity bus transportation needs. TCRP Report 79, Federal Transit Administration, Washington, D.C.

KFH Group, Inc. 2007. Washington State intercity bus service study: Draft final report. Washington State Department of Transportation, Olympia, WA.

KFH Group, Inc. 2010. Task 20: Analysis of rural intercity bus strategy, and Task 25: Evaluate requirements for the utilization of Section 5311(f) funds for intercity bus service. NCHRP Project 20-65, Transportation Research Board, Washington, D.C .

Lindly, J.K. 2009. Intercity bus service study 2007. Tuscaloosa, AL.

Transit Cooperative Research Program (TCRP). 2011. Toolkit for estimating demand for rural intercity bus services. TCRP Report 147, Transportation Research Board, Washington, D.C.

U.S. Census Bureau. 2009. Annual estimates of the resident population for incorporated places in Montana: April 1, 2000 to July 1, 2009. SUB-EST2009-04-30, Population Division, U.S. Census Bureau.

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