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# Demand Forecasting for Rural Transit

Kathleen M. Painter and Ken L. Casavant
Washington State University

## INTRODUCTION

The very nature of rural areas means that passenger needs are usually met by privately owned and operated personal vehicles. The growth in private automobiles has led to increased independence in rural areas for those who have access, physically and economically, to such vehicles. Overall, this has decreased the quantity demanded for public transportation while exacerbating the isolation of those dependent on such services.

Demand for mobility in rural towns and areas differs from that in urban areas in that the demand is less efficiently located. The density of movement, with its attendant economies of size, is very low. A fixed route, fixed schedule service may be feasible in some rural towns and areas with sufficient population or coordinated demand patterns. A demand-responsive service may be the only cost-effective way to accommodate the small number of riders in less populated areas.

Those without access to transportation in isolated rural areas may find themselves unable to take advantage of social service programs, to receive adequate medical care, to participate in the work force, or in some other way to provide for their basic human needs. This group includes the frail elderly, youth below the driving age, the physically challenged, persons without cars, one-car families with two-car needs, those without valid driver's licenses, and people whose mental capacities do not allow them to drive. This group often lacks the political leverage that could bring public attention to their problem.

This need for public transit in rural areas and communities is further exacerbated by the increase in retirement couples moving into rural communities. Farm families have historically moved into town upon retirement, usually to make way for the next generation on the farm and to access medical facilities. Today, there is a new demand from families moving to areas of lower housing costs, less crime and traffic, and to "get away from it all." These citizens may be moving from an area with access to public transportation and expect to have some public provision of services.

For a number of reasons, funding for research and planning in the area of rural transit has generally been limited. Providing for the transit needs of rural residents has a high per capita cost relative to urban transit due to the dispersion of the population over a large area. Meeting the basic needs of this population group generally takes priority over research and planning projects. In addition, since the costs of establishing or expanding service are relatively small in rural areas, misallocations are less expensive to remedy relative to urban transit investments. Finally, demand models have tended to produce unrealistically large estimates of need and, thus, have been considered relatively impractical (SG Associates, Inc., 1995). Skepticism for the planning process and the predictive power of transit models is common.

Is planning and demand forecasting really necessary for rural transit? Absolutely. Limited operating funds make planning even more crucial. Without proper coordination, there will be under- and over-served segments of the population. Public transit systems need to be well managed and coordinated in order to increase efficiency and lower the costs per rider. Legislation at different levels requires improved management practices based on monitoring of use and need. For example, the Intermodal Surface Transportation Efficiency Act of 1991 requires a state transportation plan that considers the needs of nonmetropolitan areas under Section 1025. A stated goal of the Washington State Department of Transportation's (WSDOT) State Public Transportation and Intercity Passenger Rail Plan is to provide "safe, reliable, affordable, and convenient" choices for urban, rural, and intercity travel.

In this paper, characteristics of four different county-level systems currently in use in this state are presented; these systems serve as the basis for the models developed in this analysis. Then, three models for predicting regional transit demand in rural areas for Washington State are presented. The first two models rely on Census data by population subgroup to predict potential ridership, one based on all four regional transit systems in the study and the other based on the three systems that use fares. The third model is much more detailed and allows for considerable modifications based on specific characteristics of the transit system under consideration.

## WASHINGTON STATE RURAL TRANSIT MODELS

Three Washington-based models were developed based on the characteristics of usage for four regional transportation systems currently in place in nonmetropolitan areas in Washington State. The first model, Total Transit Demand-All (TTD-ALL) uses average values for ridership by population subgroup from four regional transportation systems in Washington to predict ridership for other areas. Data needs for the model are simple, consisting of total population for the county, the population aged 65 and over, the number of mobility-limited individuals, and the number of people living below the national poverty level. All of this information is readily available from Census data. A second model uses the same approach as the first, but excludes the fare-free regional transportation system which has markedly different characteristics from the systems with fares. Ridership data from the three systems that have fares are used to produce coefficients for the second model, Total Transit Demand-FARE (TTD-FARE).

A third model, Disaggregated Transit Demand (DTD), was developed using a separate equation for each population subgroup. A random sample telephone survey was conducted in two regions, in Chelan and Douglas counties, where a fare-free transit system is available, and in Clallam County, which has a fare system in place. Values for coefficients in this model were obtained from Census data and these surveys. Sensitivity analysis was performed in order to document changes in estimated variables that would produce more accurate estimates of ridership behavior by population subgroup. For reasons beyond the scope of this study, ridership by population subgroup differed significantly by these four transit regions.

Users of the DTD model may want to use the values for the transit system in this study that is most similar to their own. This model has the potential to be much more accurate than the first two Census-based models, particularly if additional data or surveys are conducted to determine the correct values for the coefficients in the model. Ultimately, an individualized, complex model for each regional transit system could be developed as relationships between transit need and usage are uncovered. A model for any particular area will necessarily need to reflect site-specific regional characteristics and will change over time as well. These models, based on other Washington transit systems, seem to provide a reasonable starting point.

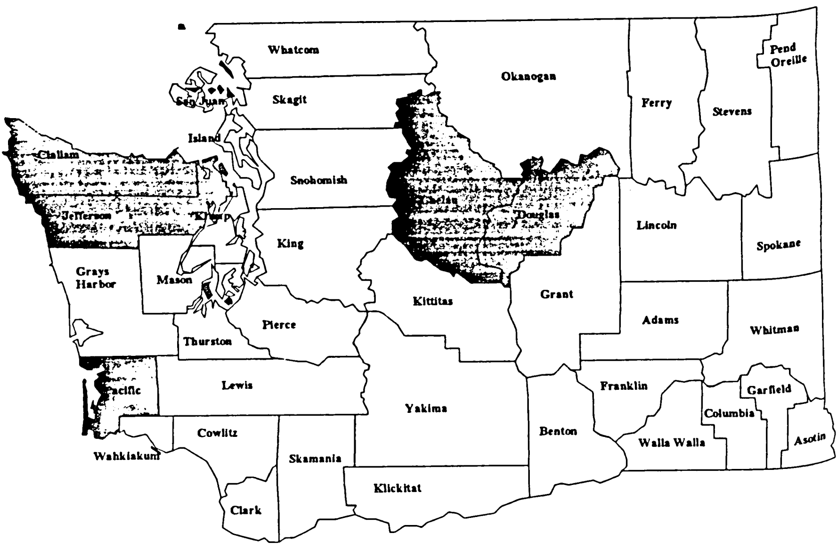
Several secondary data sources are available that provide useful information for transit planners, particularly for this case study in the state of Washington. Census data, population trends, and forecasts by county are available from the Census Bureau. The Department of Social and Health Services has detailed statistics on the number of people in each of their programs for each county (Meury, personal communication, 1998).

## Case Studies and Development of Models

Four regional transit systems located in rural areas in Washington State were able to provide detailed ridership data for use in this model (Figure 1). They include Clallam Transit

## FIGURE 1

## Case Study Regional Transportation Systems



(CT) in Clallam County, Jefferson Transit Authority (JT) in Jefferson County, Pacific Transit System (PT) in Pacific County, and LINK in Chelan and Douglas counties. Data from these systems were used to develop and test the predictive power of models which use population and ridership data to predict transportation demand. These were the only identified systems that operated in primarily rural areas on a county-wide basis that were able to provide detailed ridership data. It is apparent that separate models for public transit in rural and urban areas are needed due to substantial differences in these services. Even within these rural counties, different types of transit services are demanded. For example, some areas in these counties have public transit routes that are timely for transporting schoolchildren. In these cases, population data and model coefficients for this group will be needed.

The following table presents the ridership data from 1995 collected for each of the case study transportation systems. Riders per year by population subgroup were provided by each case study transportation system.[1] County population by subgroup was estimated from 1990 U.S. Census data. LINK in Chelan and Douglas counties has the highest average ridership at 23 rides per person per year, probably due to the fact that it is the only fare-free system in this study. Voters in this region approved a 0.4 percent sales tax in 1990 explicitly for the provision of a

[1]Note that there were no state-wide standards for data collection categories, so the groupings by population categories differed somewhat from county to county. These categories did not always provide an exact match to U.S. Census data, so some extrapolation was used in the modeling process.

fixed-route, fare-free transit system. Ridership for the entire population is lower in the other three areas, averaging 11 rides per person per year in Jefferson County, 12 in Pacific County, and 14 in Clallam County.

Higher ridership for the LINK system occurs mainly in the youth population subgroup, although ridership by the 18- to 59-year old segment of the population is also slightly higher than for the other transit systems. Use of transit systems by the disabled adult population (ages 18 to 59) varies widely among the transit systems in this study, ranging from a low of 39 rides per disabled person per year in Pacific County, to nearly 200 rides per person per year in Jefferson County. Ridership by the adult population is lowest in Clallam County, averaging 9 rides per person per year for the population aged 16 to 64. In the other three regions, ridership for this population subgroup ranged from 19 to 21 rides per person per year. For seniors, average daily ridership varied from an average of 4 rides per person per year in Jefferson County, to 10 rides per person per year in Chelan and Douglas counties.

In the following section, characteristics of each transit system in this study are described. Others using this study may want to identify the county with transit choices and characteristics most similar to their own as a model for demand forecasting purposes.

Clallam Transit System (CT) has a fixed-route service consisting of 14 routes: Two intercity routes, six urban routes, and six rural routes (three in eastern Clallam County and three in western Clallam County). Several of these fixed routes deliver passengers to two ferry operators within the county. In addition, CT services the air terminal in the county, the public schools, and Peninsula College. CT also provides connections to transit systems in Jefferson and Grays Harbor counties. Para-transit services to the elderly and persons with disabilities are provided by a private, non-profit operator. Transit services were begun in early 1980 for eastern Clallam County and early 1984 for western Clallam County.

Jefferson Transit Authority (JT) has seven fixed routes as well as a variety of other services including vanpool, ridematching, route deviation (fixed route but with the flexibility to accommodate passengers within a small radius of the route), regional, and intercity bus connections as well as connections with Washington State ferries. Several fixed route services provide easy transit access to the county's public schools. Paratransit services for persons with disabilities are provided by a private, nonprofit operator under contract with JT. Connections to the ferry terminal and to Kitsap Transit are provided seven days a week. Connections to Mason County and Clallam County transportation services are also available.

The LINK transit system located in Chelan and Douglas counties operates 17 fixed routes, three point deviation (also known as route deviation) routes, and paratransit. Seasonal transit services are provided to the ski area and the county fair. Ridesharing and vanpool programs are offered as well. LINK provides services to regional and municipal airports as well as the Lake Chelan Ferry. Bus service is also provided to the Amtrak and Greyhound depots in Wenatchee.

LINK has routes that pass by all of the public schools in the area as well as Wenatchee Valley College. LINK began operations in December of 1991.

Pacific Transit (PT) has six fixed routes. Paratransit service is provided to those with disabilities as well as to persons without easy access to fixed-route services. Fixed-route services provide timely access for public schoolchildren and provides service to Grays Harbor Community College in Aberdeen from Raymond and South Bend. PT has been in operation since 1980.

## Model Development and Results

In this section, different models for estimating ridership are presented. These models provide a starting point for transit planning as demand will always be responsive to price and quality of service factors. Predicting potential ridership for areas without transit services will be difficult, but by closely examining existing systems in this state, reasonable estimates appear within reach.

The first model, Total Transit Demand-All (TTD-ALL), was developed using data from four Washington State transit systems. The coefficients for ridership for several population subgroups are obtained using the average values (number of rides per person per year that uses the transit system, see Table 1) for the four systems in this study, with each transit system weighted equally. It takes the form of:

$$TTD\text{-}ALL\text{: } Predicted\ Rides\ Per\ Year = \frac{7.3*ELD+15*POP+100(MLADULT+MLELD)}{\%POPABOVEPOV}$$

**TABLE 1**

**Comparison of Ridership Data and Population by Case Study Counties**

| Transit System/ Population by Subgroup | Riders/Year | Population | Rides/Person/Year |
|---|---|---|---|
| **Chelan-Douglas:** | | | |
| Youth (<18) | 619,576 | 22,090 | 28 |
| Regular (18-59) | 873,337 | 41,532 | 21 |
| Senior (60+) | 147,642 | 14,833 | 10 |
| Mobility Limited (ages 16-64) | 49,042 | 702 | 70 |
| **TOTAL** | **1,689,597** | **78,455** | **22** |
| **Pacific:** | | | |
| School service (est.) | 15,651 | 3,622 | 4 |
| Adult 19-62 | 180,323 | 9,587 | 19 |
| Senior >62 | 27,607 | 4,734 | 6 |
| Mobility Limited (ages 16-64) | 9,014 | 231 | 39 |
| **TOTAL** | **232,595** | **18,882** | **12** |
| **Clallam:** | | | |
| Youth (<19) | 260,841 | 14,606 | 18 |
| Regular riders (ages 16-64) | 308,652 | 32,636 | 9 |
| Elderly (65+) | 106,492 | 11,528 | 9 |
| Mobility Limited (ages 16-64) | 101,246 | 813 | 125 |
| **TOTAL** | **777,231** | **56,464** | **14** |
| **Jefferson:** | | | |
| Children (<=6, with adult) | 7,804 | 1,595 | 5 |
| Youth (<18) | 62,532 | 2,984 | 21 |
| Adult (18-59) | 95,418 | 10,051 | 9 |
| Senior (60+) | 23,036 | 5,517 | 4 |
| **TOTAL** | **224,010** | **20,146** | **11** |

where *ELD* is the population aged 65 and over, *POP* is the total population for the county or counties, *MLADULT, MLELD* represents the mobility limited population aged 65 and over, and *%POPABOVEPOV* is the percent of the population living above the poverty level in that county. Using the variable *%POPABOVEPOV* in the denominator serves to increase the demand for transit services as the percent of the population living above the poverty level declines. The TTD-ALL model did a very good job of estimating ridership for LINK, as can be seen in Table 2. Ridership for the other three systems was overestimated by 62 percent to 112 percent. Since LINK is a fare-free system and the other three are not, it would be expected that quantity demanded is diminished in the presence of fares.

**TABLE 2**

**Estimation of Ridership per Year by Transportation System Using TTD-ALL**

| | Chelan-Douglas | Pacific | Clallam | Jefferson |
|---|---|---|---|---|
| Predicted Ridership | 1,674,552 | 461,084 | 1,306,569 | 437,842 |
| Actual Ridership | 1,692,480 | 216,944 | 806,898 | 224,010 |
| Difference | 17,928 | (244,140) | (499,671) | (213,832) |
| **% ERROR** | 1.06% | -112.54% | -61.92% | -95.46% |

To provide a better model for systems charging a fare, coefficients for these variables were estimated using the average values for the three systems with fares. This model, Total Transit Demand for Fare Systems (TTD-FARE), takes the following form:

$$TTD\text{-}FARE\text{: } Predicted\ Rides\ Per\ Year = \frac{6.4*ELD+12.5*POP+120(MLADULT+MLELD)}{\%POPABOVEPOV*1.7}$$

Coefficients for each of the variables in the TTD-FARE model were obtained from the average values for ridership for systems with fares (see Table 1). Average values for the three transit systems with fares were 17 percent lower for the population in general, 12 percent lower for the elderly, and 20 percent higher for the disabled than the average values for all systems including the fare-free system (see Table 3). Proportionately higher ridership by the disabled in areas with fares may well reflect inelastic demand for this group and the fact that their fares are often subsidized. In addition, the impact of fares on the demand for transit is reflected in the 70 percent increase in the coefficient in the denominator. This model predicts actual ridership most accurately for Jefferson County; values for actual and predicted ridership differ by just 1 percent. For Pacific County, predicted ridership was 13 percent higher than predicted, while the estimate for Clallam County was 14 percent lower than actual ridership (Table 3). For all three counties combined, the total predicted ridership was 6 percent lower than actual ridership.

**TABLE 3**

**Estimation of Annual Ridership for Systems with Fares Using TTD-FARE**

| | Pacific | Clallam | Jefferson | Total |
|---|---|---|---|---|
| Predicted Ridership | 245,257 | 696,162 | 227,194 | 1,168,613 |
| Actual Ridership | 216,944 | 806,898 | 224,010 | 1,247,852 |
| Difference | (28,313) | 110,736 | (3,184) | 79,239 |
| **% ERROR** | -13% | 14% | -1% | 6% |

In an attempt to develop a model with the potential for greater accuracy than the simple models presented above, a model that disaggregates ridership by population subgroup was developed. Sensitivity analysis reveals the variation in ridership behavior by transit system, perhaps reflecting different priorities by individual transit systems.

Two random sample telephone surveys provided data on average transit usage by population subgroup, and frequency of usage for those who commute. The fare-free LINK transit system was represented by a survey of 175 residents in Chelan and Douglas counties, while another 112 residents in Clallam County represented county transit systems with fares located on the Washington coast. These surveys were performed by the Social and Economic Sciences Research Center at Washington State University in April, 1999.

Figure 2 presents the individual equations that comprise the TTD model. Each equation is explained in detail below.

**FIGURE 2**

**Equations for the Disaggregated Transit Demand Model**

**DTD-1:** Youth Ridership = (*YOUTH*)(110)(*%youthcommute*)

**DTD-2:** Adult Ridership = (*ADULT*)(157)(*%commute*)

**DTD-3:** Senior Ridership = (*ELD*)(100)(*%eldcommute*)

**DTD-4:** Mobility-Limited Ridership = (*MLADULT*)(365)(*%mlcommute*)

**TOTAL TRANSIT DEMAND = DTD-1 + DTD-2 + DTD-3 + DTD-4**

The first equation takes the following form:

**DTD-1:** Youth Ridership = (*YOUTH*)(110)(*%youthcommute*)

where *YOUTH* represents the population aged 16 and under, 110 is the average number of trips for this age group based on survey data, and *%youthcommute* is the percentage of youth that use transit on a regular basis (once a month or more) based on survey data. Values for *%youthcommute* were considerably higher for the fare-free system (see Table 4). The estimate of 110 rides per year for this population subgroup was based on behavior for youth in the households of respondents in both regions. Results for the DTD model using empirical data from the random sample phone survey are presented in Table 5. It is interesting to note the wide range in predictive ability of this model by population subgroup. Estimates for youth ridership ranged from just 31% to 38% of actual ridership for Clallam, Chelan-Douglas, and Jefferson systems, to 170% of ridership for the Pacific County system. In order to describe ridership for this population subgroup, sensitivity analysis for the estimated variables was performed. Table 6 shows the values for percentage of the population subgroup that commutes necessary to describe actual ridership, assuming the value for frequency (rides per year) is correct. Table 7 shows the necessary value for frequency of ridership assuming the value for percentage commuting is correct. These values represent probable upper bounds for these variables; the true values for these variables will logically lie somewhere between the value for the empirical estimate and the descriptive estimate. If one adjusts the descriptive model by percentage of youth using transit, ridership estimates would range from a high of 30% of the youth using transit in the Chelan-Douglas region, to 20% in Clallam County, 16% in Jefferson, and a low of 4% of the youth in Pacific County. If the descriptive model is adjusted solely using the frequency variable, average rides per year would have to rise to well over 300 for Chelan-Douglas, Clallam, and Jefferson counties, and fall to 65 one-way rides per year for Pacific County.

**TABLE 4**

**Transit Usage By Population Subgroup By Transit Region**

| | *%youthcommute* | *%commute* | *%eldcommute* |
|---|---|---|---|
| LINK Transit area (fare free system) | 10 | 13 | 10 |
| Clallam Transit area (fare system) | 6 | 10 | 7 |

**TABLE 5**

**Comparison of Predicted to Actual Values for Ridership Estimation Equations by Regional Transportation System**

| | **Chelan-Douglas** | | **Pacific** | | **Clallam** | | **Jefferson** | |
|---|---|---|---|---|---|---|---|---|
| Ridership: | *Predicted* | *Actual* | *Predicted* | *Actual* | *Predicted* | *Actual* | *Predicted* | *Actual* |
| YOUTH (K-12) | 214,401 | 619,576 | 26,558 | 15,651 | 81,180 | 260,841 | 26,855 | 70,336 |
| ADULT (16-64) | 971,557 | 873,337 | 169,089 | 180,323 | 512,385 | 308,652 | 186,987 | 95,418 |
| ELDERLY (65+) | 113,620 | 147,642 | 28,616 | 27,607 | 80,696 | 106,492 | 29,169 | 23,036 |
| MOB. LIM.16-64 | 51,246 | 49,042 | 18,863 | 9,014 | 59,349 | 101,246 | 12,994 | 35,220 |
| **TOTAL** | 1,350,826 | 1,689,59 | 241,130 | 232,595 | 733,613 | 777,231 | 256,009 | 224,010 |
| Difference | (338,771) | | 8,535 | | (43,618) | | 31,999 | |
| **% ERROR** | -20% | | 3.7% | | -5% | | 14% | |

## TABLE 6

**Sensitivity Analysis for Proportion of Population Subgroup Using Transit Services by Regional Transportation System**

| | Chelan-Douglas | | Pacific | | Clallam | | Jefferson | |
|---|---|---|---|---|---|---|---|---|
| Population Subgroup: | Model | Adjusted | Model | Adjusted | Model | Adjusted | Model | Adjusted |
| Youth (<16) | 10 | 30 | 6 | 4 | 6 | 20 | 6 | 16 |
| Adult (16-64) | 13 | 12 | 10 | 11 | 10 | 6 | 10 | 5 |
| Elderly (65+) | 10 | 12 | 7 | 7 | 7 | 10 | 7 | 8 |
| Mobility Limited (16-64) | 20 | 20 | 20 | 10 | 20 | 3.5 | 20 | 55 |
| **% ERROR** | -20% | 2% | 3.7% | 3.5% | -5% | 2.6% | 14% | 1% |

## TABLE 7

**Sensitivity Analysis for Ridership Frequency (average one-way rides per person per year) by Population Subgroup Using Transit Services for Each Regional Transportation System**

| | Chelan-Douglas | | Pacific | | Clallam | | Jefferson | |
|---|---|---|---|---|---|---|---|---|
| Population Subgroup: | Model | Adjusted | Model | Adjusted | Model | Adjusted | Model | Adjusted |
| Youth (<16) | 110 | 313 | 110 | 65 | 110 | 365 | 110 | 313 |
| Adult (16-64) | 157 | 156 | 157 | 170 | 157 | 100 | 157 | 80 |
| Elderly (65+) | 100 | 130 | 100 | 100 | 100 | 133 | 100 | 80 |
| Mobility Limited (16-64) | 365 | 365 | 365 | 190 | 365 | 626 | 365 | 1000 |
| **% ERROR** | -20% | 5% | 3.7% | 1.5% | -5% | 3.5% | 14% | 3% |

**DTD-2:** Adult Ridership = (*ADULT*)(157)(*%commute*)

where *ADULT* is the population aged 16 to 64, 157 represents the average number of one-way rides per year for this population subgroup, and *%commute* is the percentage of the adult population that commutes on a regular basis. The difference between predicted and actual ridership ranged from a negative 6% for Pacific County to a positive 11% for Chelan and Douglas counties, a positive 66% for Clallam County, and a positive 96% for Jefferson County. Sensitivity analysis revealed that the value for the percentage of the population subgroup using transit would need to be reduced by 1% in Chelan and Douglas counties, increased by 1% in Pacific County, decreased by 4% for Clallam County, and decreased by 5% for Jefferson County in order to have reasonable ridership estimates for adult riders, producing a predictive error of less than 5% in each transit region (Table 6). Sensitivity analysis on the frequency of ridership variable shows that the average annual rides per adult commuter require the largest adjustments in Clallam and Jefferson counties, with frequency reductions of one-third in Clallam County and nearly one-half in Jefferson County (see Table 7). Better estimates for the variables of interest for this population subgroup can be attributed to larger numbers of adult respondents in the telephone survey (36 adult riders compared to 24 youth riders).

**DTD-3:** Senior Ridership = (*ELD*)(100)(*%eldcommute*) here *ELD* represents the population aged 65 or over, the value 100 represents approximately two roundtrip rides on the transit system per week, and *%eldcommute* is an estimate of the percentage of the elderly population that uses the transit services. The values for the second and third terms were obtained from the random sample telephone survey. For the fare-free system, the percentage of the elderly population using transit services was estimated at 10 percent; for the systems with fares, this percentage declined to 7 percent. Predicted values ranged from approximately one-quarter below actual ridership values for Chelan-Douglas system to 27% above actual ridership for Jefferson County (Table 5). Predictions for Pacific County were within 4% of the actual value. Sensitivity analysis was performed on the values for *%eldcommute* and the frequency of ridership for this subgroup in Tables 6 and 7.

**DTD-4:** Mobility-Limited Ridership = *(MLADULT)*(365)(*%mlcommute*)

where *MLADULT* represents the population aged 16 to 64 classified by the Census as mobility limited, 365 represents six roundtrip rides on transit services every week, and *%mlcommute* is an estimate of the percentage of the non-elderly adult population with mobility limitations that uses the transit services. This group was not represented in the random sample survey; values for these variables represent reasonable estimates by the researchers for this subgroup. The ridership of mobility-limited elderly was not estimated separately in this model; it was assumed that these riders are more likely to have transit needs similar to the elderly population.

The sum of equations 1 through 4 gives the total ridership estimate. There is just 1 percent error overall, comparing total predicted ridership to total actual ridership across the four systems, although the ridership estimates by transit system are substantially lower at 20% for the Chelan-Douglas system and substantially higher at 14% for the Jefferson County system. These results show how difficult it is to apply a single, simple model across various regions and systems. Better estimates could be obtained with additional data on the different subgroups that use public transit each year. Surveys of the general population are quite costly to perform at the level needed to obtain adequate numbers for each area. Developing one model and applying it to other areas ignores characteristics such as transit priorities, geographical differences, travel patterns, demographic patterns, and other factors that may be critical to a model's predictive ability. If a transit system is already in place, ridership surveys are generally a less expensive and less time consuming method for obtaining estimates of average number of rides per year by different population subgroups than surveys of the general population. If total ridership data are already available, ridership by subgroup can be determined by conducting a ridership survey that documents the proportion of riders in each population subgroup. Unlike other models, this model classifies riders into fairly easily identifiable subgroups that do not require further classification by characteristics that often are deemed offensive, such as income level or race. However, a more sophisticated approach which took other factors into account may have better predictive ability, especially for estimating ridership in areas currently without transit systems.

Planners and analysts using these models may wish to choose values for the coefficients from the county or transit system that seems most similar to one they are studying. They may find that some fairly simple data gathering will improve the estimates obtained from these models. For example, a statistically representative survey of persons classified as mobility limited would not require a large number of surveys in most cases. Secondary data sources may also provide some of the data needed to correctly estimate these equations. Individual planners may have a better idea of the underlying structure of the demand for transit services by a particular subgroup and may want to substantially modify the estimation technique. Hopefully, this model has provided a starting point for developing accurate equations for predicting transit need and demand for underserved areas around the state.

## CONCLUSIONS

Models with varying levels of complexity are presented for predicting transit ridership for county-wide systems. The first model, Total Transit Demand-ALL (TTD-ALL), provides an easy way to make an initial estimate of potential ridership for fare-free transit systems similar to LINK in Chelan and Douglas counties. In the second model, Total Transit Demand-FARE (TTD-FARE), ridership for the three transit systems charging fares was estimated using coefficients obtained from average values for these three systems. This model provided the closest ridership estimate for Jefferson County, with just 1 percent difference between actual and predicted ridership. The estimate for Pacific County was 13 percent higher than actual ridership, while the estimate for Clallam County was 14 percent lower than actual ridership. The third model, Disaggregated Transit Demand (DTD), used values from a random sample survey conducted in Chelan, Douglas, and Clallam counties. This model, DTD, uses empirical ridership data by subgroup combined with Census data to estimate the percentage of that subgroup using transit services. Ridership estimates from this model were 20% below actual figures for the fare-free Chelan-Douglas system and 5% lower than actual figures for Clallam County. Predictions for Pacific County were just 4% higher than actual ridership, while ridership estimates for Jefferson County were 14% higher than actual ridership. Differences by population subgroup between actual and predicted ridership highlight areas of the model needing additional work. In particular, ridership by the Youth group (aged 16 and under), were poorly characterized in this model, perhaps due to the fact that just 24 respondents had youth using transit on a regular basis in their household. Due to lack of respondents in the adult population with mobility limitations, researchers provided their own estimates for this subgroup. Planners can easily tailor these models to individual regions by using different values for various coefficients based on data or their informed estimates. Finally, simple on-board surveys, surveys of affected individuals, or additional surveys of the general population may be conducted to refine the data used for this model. The models are easy to understand and alter.

Creating a simple model that accurately predicts ridership for any particular region is a very difficult task, due to the complex nature of the problem. Accurate models for predicting rural transit demand will need to be tailored to each individual region and its population. Characteristics including the location of different services in a specific region that will generate transit need, such as medical and shopping centers, will obviously be important. In addition, the location of roads and other physical characteristics of an area can be a determining factor for transit flows. Surveys of the population can help planners determine the relationship between need and demand, although respondents sometimes tend to overestimate their actual usage. As sophisticated Geographical Information Systems become available, many different types of transit-related characteristics can be mapped, providing for coordination among transit providers and, possibly, the development of extremely accurate transit models. These models will need to reflect the dynamic nature of transit need and demand, which is dependent on a myriad of factors including population demographics, public services provided, economic cycles, and the price and quality of transit services, among others. Hopefully, an increased understanding of the relationships between these characteristics will help transit planners provide superior systems for all citizens in both rural and urban areas.

## SUMMARY

Demand forecasting for rural transit is a tool that will aid rural planners and analysts in the allocation of scarce resources for this typically underserved population. Three Washington models presented here are based on the characteristics of usage for several regional transportation systems currently in place in nonmetropolitan areas in Washington State. The first model, Total Transit Demand-All (TTD-ALL) uses average values for ridership by population subgroup from four regional transportation systems in Washington to predict ridership for other areas. A second model, Total Transit Demand-FARE (TTD-FARE) uses the same approach as the first, but excludes the fare-free regional transportation system which has markedly different characteristics from the systems with fares. A third, more in-depth model, Disaggregated Transit Demand (DTD), was developed using a separate equation for each population subgroup. Sensitivity analysis reveals that ridership behavior by population subgroup differs significantly across the four transit systems in this study; accurate descriptions of ridership by population subgroup require adjustments for these differences.

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