Rural Transit Demand Estimation: An Alternative Approach in the State of Washington

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DEMAND FORECASTING FOR RURAL TRANSIT

ABSTRACT
Rural transit demand forecasting is a tool that aids planners and analysts in the allocation of scarce resources for typically underserved populations. As the number of privately owned automobiles has increased over the last several decades, provision of public transportation has decreased, lessening non-drivers ability to participate in the workforce, take advantage of social service programs, and to receive adequate medical care. Using Washington as the case study, three models were developed based on the characteristics of usage for several transportation systems currently in place in four Washington counties. Peer analysis was used to create models with varying levels of complexity and data requirements to predict ridership on county-wide public transportation systems. Of the three models, the Disaggregated Transit Demand (DTD) model estimation techniques are the most refined and flexible. This model provides a significant starting point for developing accurate equations for predicting transit need and demand for underserved areas around the state.

Key words: Demand, Forecast, pubic transit, rural.

INTRODUCTION

In rural areas, as more people have come to depend on private automobiles, the demand for public transportation has decreased, making transit systems less economically feasible. Paradoxically, for those who do depend on public transportation, the need for transit services has increased and it is often the elderly, the physically or mentally disabled, the poor, or the young who are affected the most by the loss of service in rural areas. The consequence is that non-drivers in isolated rural areas may be unable to take advantage of social service programs, receive adequate medical care, participate in the workforce, or in some other way provide for their basic needs without depending on family and friends for transportation.

Demographic trends in rural areas are likely to have a considerable influence on the demand for public transportation. According to Census figures, there were 78.2 million baby boomers in 2005 and by 2011 the oldest boomer will begin turning 65 *(1)*. As the number of people over 65 increases, a lack of public transportation in rural areas could limit access to health care services or other social service for elderly residents, especially if they are unable to find other means of transportation. Similarly, demographic trends from migration can also impact the need for public transportation. Low-priced housing, less traffic, lower crime rates, and natural beauty make rural areas appealing places to live. Non-metropolitan growth rates increased in the early 1990s, declined in the late 1990s but then increased again in the early 2000s *(2)*. Even migration trends with population growth outside the urban fringe to "exurbs" could affect transportation needs in low-density areas. These population shifts have implications for policy-makers and planners since transportation systems provide support for the elderly, the disabled, the poor, and the young. Without planning and demand forecasting, it is likely that those most in need of public transportation will be under-served and unable to access the services and programs designed to provide assistance. By using demand forecasting as a tool, rural planners and policy makers may be better able to serve different community groups and allocate resources more effectively.

Transportation planning for rural areas, however, provides different challenges than planning for urban areas because rural demand is less efficiently located and the density of movement is very low. A dependable fixed route, fixed schedule service may be feasible in some rural towns and areas with sufficient population or coordinated demand patterns. A highly flexible demand-responsive service that has both flexible routes and schedules, however, may be a more cost-effective way to accommodate a small number of riders in less populated areas. For instance, rural non-drivers who may need further transportation assistance once they have reached their initial destination could benefit from a demand-responsive service, especially if taxi service is unavailable.

Unfortunately, funding for rural transit research and planning has generally been limited and demand models have been considered relatively impractical because they tend to produce unrealistically large estimates of need *(3)*. However, public transit legislation has increasingly required improved management practices based on monitoring of use and need. For example, under Section 1025 of the Inter-modal Surface Transportation Efficiency Act of 1991, states are required to consider the non-metropolitan needs in any transportation plan. In addition, one 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 inter-city travel. Consequently, the results of a federal effort to develop demand forecasting for rural passenger transportation served as the starting point of this state-level research project to provide a model for rural transportation planners in Washington State (SG Associates, Inc., 1995), referred here to as the TCRP Report. The article reports on the feasibility of the TCRP methods for the State of Washington, determines what is applicable, and then develops a series of state-specific rural transit planning models based on existing systems in this state.

A Brief Review of the TCRP Report

The TCRP Workbook models are designed to estimate demand for passenger transportation services in rural areas, defined as those outside of a Metropolitan Statistical Area (MSA) and with a population density of less than 1,000 persons per square mile. Demand estimation methodology in the TCRP Workbook relies on two distinct types of passenger transportation demand, namely program-related demand and non-program related demand. Program-related demand is defined as trips that would not occur but for the existence of specific social service program activities. Non-program related demand is defined as all other trips. Two methods are used in this report: an *incremental method* for when passenger transportation services already exist, and a *synthetic method* that is designed for counties without transit services for one or more groups.

TCRP models were developed using data from over 200 passenger transportation services in 39 rural counties. Data used to predict potential need for rural transit services include variables such as the number of elderly and mobility-limited people. Program-related transportation is estimated based on the number of participants for various categories of social service programs, such as Headstart, job training, or mental health services. These equations represent the synthetic demand estimation approach and are simple linear equations predicting the number of expected annual trips given the level of participants in a particular program *(see 4, for a detailed review of this report and the modeling equations)*. Many of the estimates in the TCRP Workbook, however, were performed with just a few valid samples and the categories do not necessarily coincide with specific county programs. For example, senior nutrition transit demand numbers may be confounded because seniors' meals are served at their place of residence in some areas, and at centrally located facilities (thus requiring public transit) in other areas.

Non-program-related demand is estimated as a function of the size of the three population groups most likely to use a rural passenger service (the elderly, persons with mobility limitations, and persons in poverty), the size of the service area, and the amount of service available to each of these three population groups in annual vehicle miles. There are two fundamental problems, however, with how this model is used to estimate these demand relationships. First, statistically the equation assumes that the proportion of road use to county area is a determining factor of demand. This is not necessarily the case, as some rural areas with high transit needs have a large number of roads across a geographic area, and others have much less, due to geographic characteristics, housing characteristics, land use, and state highway budgets, to name a few. Therefore, it is difficult to predict demand accurately for counties such as those in Washington State because these characteristics vary considerably from one county to another.

The second and more significant concern with the non-program demand equation is the lack of county-level data to estimate annual vehicle miles by population subgroup in Washington and probably other states as well. As is noted in the TCRP report, few agencies in the 39 county sample were able to provide vehicle miles for each population subgroup *(3)*. Instead, they obtained data or estimates of total non-program ridership for all groups and then calculated the coefficients for each subgroup using an iterative process until reasonable results with low error were obtained. Since information on vehicle miles by these subgroups is not generally available a number of individuals at the state and county levels in Washington were contacted in an unsuccessful attempt to gather the necessary data to test these models (Karl Johansen, "unpublished data", Executive Director, Council on Aging, Colfax, WA, 1997) (John Riemel, "unpublished data", Executive Director, People for People, Yakima, WA, April 1997) (Paul Meury, "unpublished data", Budget Division, Office of Research and Data Analysis, Department of Social and Health Services, Olympia, WA, 1997 and 1998) (Pat White, "unpublished data", Manager, Medical Assistance Customer Service Center, Division of Client Services, Department of Social and Health Services, Olympia, WA, March 1997). These data would have to be collected in order to use the TCRP method. This poses some difficulty because not only would each rider have to be classified into one of the three groups (i.e., elderly, mobility-limited, and below the poverty level) but the ride would also have to be non-program related and often there is no actual distinction between program and non-program related transit services. The massive effort required to gather these data (assuming people were willing to provide it, which could be personally intrusive and perhaps violate some type of privacy or ethical statute) is not cost effective given the lack of breadth in the sample used to construct the initial model in the first place.

Although these rural transit demand models suggest the relevant variables to be used, they do not provide a practical solution for rural transit demand estimation for many reasons. Data required for using the model are simply not available in most cases. Often, there is no actual separation between program and non-program related ridership and obtaining separate ridership figures by these two characteristics may be unrealistic. In addition, the model is only designed to work for counties for which the largest town has a population between 5,000 and 10,000, and the model should not be used if there are any fixed route transit services being used already (Frank Spielberg, "unpublished data", SG Associates, Inc., Annandale, VA, April 1997). Thus, this very general model developed for national use would be unlikely to have the desired predictive power for any one county in any particular state, and there are a number of counties for which the models would not be applicable.

WASHINGTON STATE RURAL TRANSIT MODELS

Given the lack of individual system applicability of the TCRP model, three Washington-based models were developed based on the characteristics of usage for several regional transportation systems currently in place in four counties in Washington State. Theoretically, it makes sense that transit programs for similar regions should have more in common than ones that are in different regions of the country. Population characteristics and the transportation infrastructure are more likely to be similar, thus producing a more constructive model than a random sample of transit systems for the entire nation, as used in the TCRP approach.

Four regional transit systems in Washington State provided detailed ridership data for our models. They include Clallam Transit in Clallam County, Jefferson Transit Authority in Jefferson County, Pacific Transit System in Pacific County, and LINK in Chelan and Douglas counties (see Figure 1). These were the only identified transportation systems operating primarily in rural areas on a county-wide basis that could provide detailed ridership data.

County population by subgroup was estimated from 1990 US Census data. Ridership data for each of the case study transportation systems by population subgroup is provided in Table 1. LINK in Chelan and Douglas counties has the highest average ridership at 22 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 fixed-route, fare-free transit system.

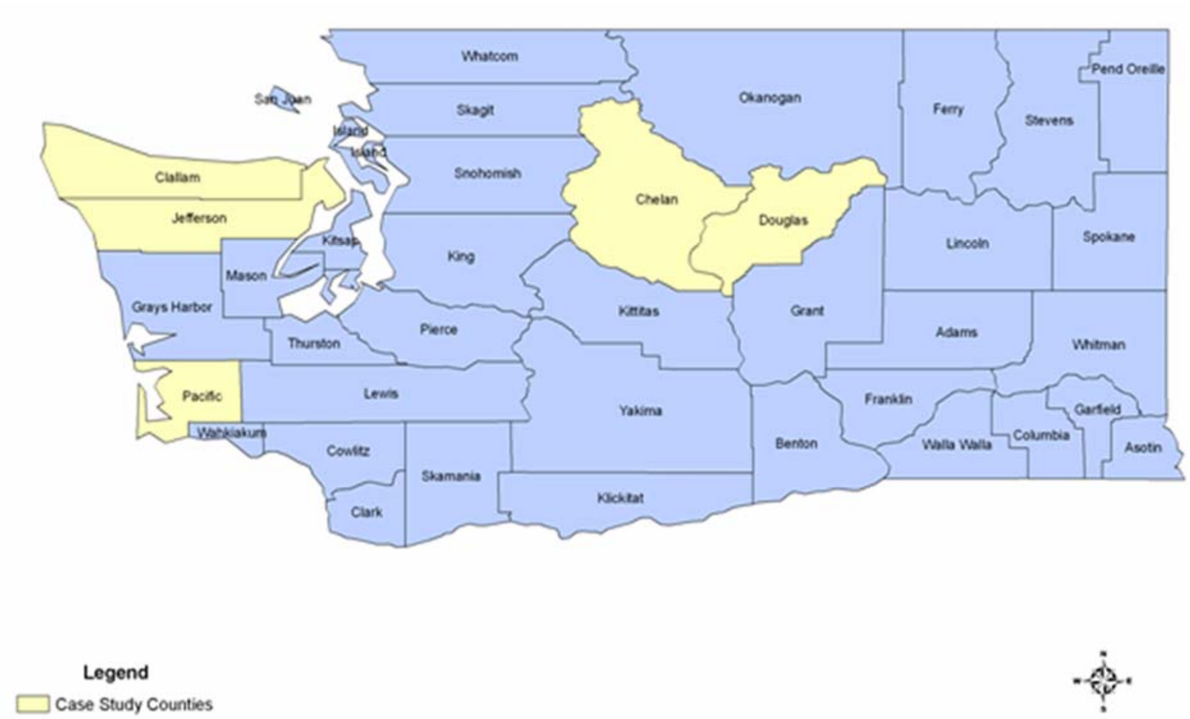

FIGURE 1 Washington case study counties.

The youth population subgroup has the highest ridership in the LINK system in Chelan-Douglas when compared to seniors or those with limited mobility. Adult ridership (ages 18-59) is slightly higher than the youth group but they also make up a larger segment of the population. Ridership is lower in the other three areas, ranging from a low of 11 rides per person per year in Jefferson County to about 14 in Clallam County. Pacific County has the lowest ridership for the limited-mobility (disabled) population, with 39 rides per disabled person per year, while Jefferson has the highest number of disabled persons per year, averaging nearly 200 disabled persons per year.

Ridership by the general population is lowest in Clallam County, averaging 9 rides per person per year for the population aged 16 to 64. Ridership for this population subgroup varied little, ranging from 19 to 21 rides per person per year in the other systems. 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. Figure 2 provides a graphical view of ridership by population subgroup.

TABLE 1 Comparison of Ridership Data and Population by Case Study Counties[a]

Transit System/ Population by Subgroup	Riders per Year	Population	Rides per Person per 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
Mobility Limited (ages 16-64)	178	35,220	98
TOTAL	**224,010**	**20,146**	**11**

[a] 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 US census data, so some extrapolation was used in the modeling process.

Three Models Estimating Demand

The first model, Total Transit Demand-All (TTD-ALL), predicts ridership using average values for ridership by population subgroup from the four regional transportation systems in Washington. Data needs for the model (available through the Census, though changes from 1990 to 2000 definitions should be noted) are total county population, population aged 65 and over, the number of mobility-limited individuals and the number of people living below the national poverty level. Ridership coefficients for several population subgroups were calculated using the average values (number of rides per person per year who use the transit system, see Table 1) of the four systems in this study, with each transit system weighted equally. Expanding on the TCRP Workbook methodology, the equation takes following form:

$$TTD\text{ - }ALL : Predicted\ Rides\ Per\ Year = \frac{7.3 * ELD + 15 * POP + 100(ML16\text{ - }64 + MLOVER64)}{\%POPABOVEPOV}$$

where ELD is the population aged 65 and over, POP is the total population for the county or counties, (ML16-64 and MLOVER64) is the population aged 16 and over that is mobility limited, 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 is shown in Table 2. Ridership for the other three systems, however, was overestimated by 62% to 112%. Since LINK is a fare-free system and the other three are not, it would be expected that demand is diminished in the presence of fares.

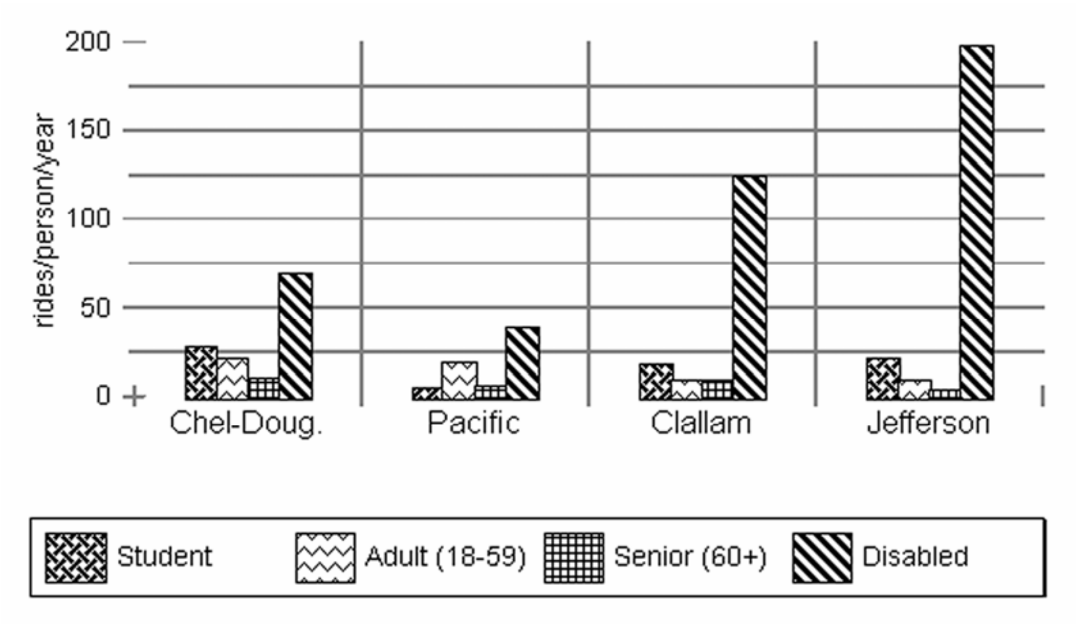

FIGURE 2 Ridership by population subgroup.

TABLE 2 Estimation of Ridership per Year by Transportation System Model 1 (TTD-ALL)

	Chel-Doug. (LINK)	**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%

Since the fare-free regional transportation system has markedly different characteristics from the systems with fares, it was excluded in the second model. Ridership data from the three fare systems are used to estimate coefficients for the second model, Total Transit Demand-FARE (TTD-FARE). This model took the following form:

$$TTD - FARE : Predicted\ Rides\ Per\ Year = \frac{6.4 * ELD + 12.5 * POP + 120(ML16 - 64 + MLOVER64)}{\%POPABOVEPOV * 1.7}$$

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% lower for the population in general, 12% lower for the elderly, and 20% 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 reflect the fact that their fares are subsidized. In addition, the adjustment for the impact of the population below poverty level is greater in this model due to the fares, so the coefficient on this variable increased by 70%. This model predicts actual ridership most accurately for Jefferson County; there is only a 1% difference between actual and predicted ridership. For Pacific County, predicted ridership was 13% higher than actual ridership, while the estimate for Clallam County was 14% lower than actual ridership (Table 3). For all three counties combined, the total predicted ridership was 6% lower than actual ridership.

TABLE 3 Estimation of Ridership Per Year For Systems With Fares, Model 2 (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%

The third model, Disaggregated Transit Demand (DTD), was developed using a separate equation for each population subgroup to reflect different characteristics for each county. One advantage of this model is that the user can modify it to create a custom measure reflecting the individual characteristics of a region and that region's approach to rural transit. For example, if a large percentage of schoolchildren regularly commute, this factor will be captured in that segment of the model, improving overall accuracy of the total ridership estimate. Furthermore, fares are not explicitly taken into account; these models could represent systems with or without fares. Average coefficients representing ridership by population subgroup reflect price and quality factors of the four systems upon which these models are based. The entire set of equations in presented is Figure 3. Each equation is explained in detail below.

DTD-1: Youth Ridership = (*%URB*)(*YOUTH*)(360)(%*transit for school*)

DTD-2: Adult Ridership, Above Poverty = (*ADULT**%*ABOVEPOV**500*%*commute*)

DTD-3: Adult Ridership, Below Poverty = %*POV***ADULT**626*%*povcommute*

DTD-4: Senior Ridership = *ELD**104*%*eldcommute*

DTD-5: Mobility-Limited Ridership = *MLADULT**626*%*mlcommute*

TOTAL TRANSIT DEMAND = DTD-1 + DTD-2 + DTD-3 + DTD-4 + DTD-5

FIGURE 3 Equations for the disaggregated transit demand model.

The first equation takes the following form:

DTD-1: Youth Ridership = (*%URB*)(*YOUTH*)(360)(%*transit for school*)
where YOUTH is the number of persons under 16 years old, %URB reflects the population distribution between rural and urban areas in the region, 360 represents the number of one-way trips for a school year with 180 school days, and %transit for school (the percentage of schoolchildren using transit services) is an estimated coefficient that can be varied from county to county. Values for capitalized variables can be readily obtained from Census data while values for lower-case variables are estimated in each regional application. We have used estimates obtained from ridership by subgroup when available for the transit systems in this study.

DTD-2: Adult Ridership, Above Poverty = (*ADULT**%*ABOVEPOV**500*%*commute*)
where ADULT is the population aged 16-64, %ABOVEPOV is the percentage of the population living above the poverty level, 500 represents the number of one-way rides assuming 250 workdays per year, and %commute is the percentage of the adult population living above the poverty level that commutes on a regular basis. The value for %commute can be estimated separately for each individual county to reflect different areas of the state, or the values listed in Table 5 can be used. (These were estimated from data obtained from the county-wide systems in this study.)

DTD-3: Adult Ridership, Below Poverty = %*POV***ADULT**626*%*povcommute*
where %POV is the percentage of the population living below the poverty level, and 626 represents the number of one-way trips (assuming roundtrip rides) on the transit system six days per week (assuming transit services are used for work as well as weekend errands for citizens living below the poverty level), and %povcommute is the percentage of the adult population living below the poverty level that commute. All other values are the same as in equations DTD-1 and DTD-2.

DTD-4: Senior Ridership = *ELD**104*%*eldcommute*
where ELD represents the population aged 65 or over, the value 104 represents two roundtrip ride on the transit system per week, and %eldcommute is a weighted estimate of the percentage of the elderly population that uses the transit services

DTD-5: Mobility-Limited Ridership= *MLADULT**626*%*mlcommute*
where MLADULT represents the population aged 16 to 64 classified by the Census as mobility limited, 626 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. While there may be many who use the transit system less frequently, this is useful simply as an initial estimation technique. As the quality of transit services improve, the

average use for various population subgroups is expected to increase and these values will need to be updated from subsequent surveys.

The sum of equations 1 through 5 gives the total ridership estimate. This is expected to provide more accurate results than the general models using average values presented in the TTD-ALL and TTD-FARE. As data become available over time or from system to system, the model can be updated and improved for each county.

By allowing certain values to vary, such as the percentage of youth or adults that used the transit system regularly, we achieved estimates extremely close to the actual ridership values in our Washington State counties (see Table 4). As more data is collected, even better estimates can be generated. For example, the percentage of each subgroup that uses public transit and the average number of times riders in different subgroups use public transit each year could be collected by administering general population and ridership surveys. Ridership surveys, in particular, can provide estimates of average number of rides per year by different population subgroups.

TABLE 4 Estimation of Ridership per Year, Model Three (DTD)

	Chelan-Douglas (LINK)		**Pacific**		**Clallam**		**Jefferson**	
Ridership:	*Predicted*	*Actual*	*Predicted*	*Actual*	*Predicted*	*Actual*	*Predicted*	*Actual*
YOUTH (<16)	625,718	619,576	16,603	15,651	264,554	260,841	69,653	70,336
ADULT (16-64)	374,254	873,337	75,869	180,323	150,615	308,652	33,317	95,418
ADULT, POV[a]	478,268		71,758		162,773		64,115	
ELD	147,845	147,642	37,565	27,607	105,789	106,492	40,310	23,036
ML16-64	8,039		15,299		33,414		7,192	
MLELD (65+)[b]	42,063	49,042	20,949	9,014	37,036	101,246	7,814	35,220
TOTAL	1,676,187	1,689,597	238,043	232,595	754,180	777,231	222,402	224,010
Difference	(13,410)		5,448		(23,051)		(1,608)	
% ERROR	-0.79%		2.34%		-2.97%		-0.72%	

[a] Adults living below the poverty level are included with adults in the actual ridership data.
[b] Mobility-limited aged 16-64 are included with the disabled aged 65 or over in the actual ridership data.

In addition, planners may wish to use their own values for the coefficients in the model, such as the percentage of the population aged 16 to 64 who commute regularly and the percentage of schoolchildren who use the transit system. Values for selected coefficients used in the model are presented in Table 5. Planners should choose values for a county or transit system that seems most similar to one they are studying. 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.

Finally, secondary data sources may also provide some of the data needed to correctly estimate these equations. Planners may have a better idea of the underlying structure of their demand for transit services for a particular subgroup and may want to substantially modify the estimation technique.

TABLE 5 Values for Selected Coefficients By Transportation System

	Chel-Doug. (LINK)		Clallam (CTS)	Jefferson (JT)
Total population *(POP)*	78,455	18,882	56,464	20,146
Rural population	35,878	15,981	29,657	10,403
Percent urban population *(%URB)*	46	85	52	52
Percent of population below poverty *(%POV)*	14	17	12	13
Mobility-limited population aged 16 to 64 *(ML16-64)*	702	231	813	178
Mobility-limited population over 64 *(ML 65+)*	1,095	476	1,356	291
Percent of youth using transit for school *(%transitforschool)*	36	3	21	17
Percent of adults living above poverty level who commute regularly *(%commute)*	8	4	4	3
Percent of mobility-limited population under 65 who commute regularly *(%mlcommute)*	25	25	25	25
Percent of adults living below poverty level who commute regularly *(%povcommute)*	50	15	25	25

CONCLUSIONS

Using peer analysis, which studies transit systems in similar areas, models with varying levels of complexity and data requirements were created to predict ridership on public transportation systems for county-wide systems. Of the three models, the Disaggregated Transit Demand (DTD) model estimation technique is the most refined and flexible. It is also more complex than the other two models but it has the potential to be much more accurate, especially if additional data or surveys are conducted to determine the specific values for the coefficients, reflecting the region being analyzed. This model provides a starting point for developing accurate equations for predicting transit need and demand for underserved groups in areas around the state.

Accurate models for predicting rural transit demand can be and will need to be tailored to each individual region and its population. The location of roads and other physical characteristics of an area can be a determining factor for transit flows. Surveys of sub-populations can help analysts determine the relationship between need and demand, although respondents sometimes tend to overestimate their actual usage. As applied Geographical Information Systems become more available, many different types of transit-related characteristics can be mapped, such as location of services, providing for coordination among transit providers and, possibly, the development of even more sophisticated and 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. An increased understanding of the relationships between these characteristics will help develop transit systems of the future that provide cost effective systems for all citizens in both rural and urban areas.

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