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Description of Econometric Models That Forecast the Demand for Construction Aggregates in Oregon Counties

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Summary

This report provides technical details about the structure and equations used in a long-term model of aggregate demand in Oregon. The model forecasts housing, road mileage, construction activities, and the consumption of construction aggregates by county on an annual basis from 2001 to 2050. This report explains how to use the model to run different economic and demographic scenarios. It also shows how the model can be modified to forecast aggregate consumption for places other than Oregon.

This report is a companion piece to Special Paper 27 which is entitled “ An Economic Analysis of Construction Aggregate Markets and the Results of a Long-Term Forecasting Model for Oregon.” Special Paper 27 describes many useful insights about the relationships between aggregate consumption, the economy, and growth. In addition, it summaries the forecasts for Oregon’s 36 counties.

The complete forecasts for each county are on this CD-ROM. The forecasts are contained in models written in Lotus 123. There is a separate model for each county.

Notice

The Oregon Department of Geology and Mineral Industries is publishing this paper because the subject matter is consistent with the mission of the Department. To facilitate timely distribution of information, this manuscript has not been edited to our usual standards.

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Chapter One
Basic Structure

Introduction

The Department of Geology and Mineral Industries built a forecasting model for every county in Oregon. The models all have the same structure, but operate with different sets of input data that reflect the unique characteristics of each county. The models are designed to forecast long-term trends for a 50-year period beginning in 2001 and ending in 2050. They contain large amounts of data and many equations.

There are four parts to each county model. The first contains basic input data about the county. The next part uses these data to project a county's need for housing, roads, and other construction. This is followed by forecasts of usage rates. A usage rate is the amount of aggregate consumed for a given unit of construction. For example, the usage rate for schools is measured in tons of aggregate needed to construct 1,000 square feet of a new school building. The final part of the model multiplies the construction and usage-rate forecasts to give us projections of total aggregate consumption.

The models use demographic forecasts to predict aggregate consumption. Demographic forecasts consist of projections for population by age group, numbers of households, and personal income. Users can change any of these to suit their own opinions about a county's growth prospects. Users can also change the equations that convert the demographic data into aggregate forecasts.

Besides demographics, other data are fed into the models that help describe differences between counties. For example, there is one that indicates whether or not a county has a commercial airport. It is used in an equation that forecasts the construction of airport buildings.

Each model divides a county's construction activity into 33 categories. These include schools, gravel roads, high-rise apartments, bridges, parking garages, manufacturing plants, and stores. Building construction is measured in the models in terms of thousands of square feet. Other types of construction, like sewers and dams, are expressed in thousands of 1987 dollars.

The term "1987 dollars" means that the cost of the construction is stated in what it would have been if it had occurred in 1987. That way, no matter what year we are looking at, construction values are in the same dollar terms. This is a standard forecasting practice, and it eliminates distortions caused by inflation. The year 1987 was chosen for convenience. The choice has no practical effect on the aggregate forecast.

FW Dodge is the source for most of the construction data. We used the historical data on construction from FW Dodge to make our own forecasts. FW Dodge is the construction industry's leading statistical analysis firm. Nearly all major construction companies report data to it. FW Dodge is the only source of detailed construction data for Oregon's counties. FW Dodge claims to capture 90% of the new construction in Oregon. Our forecast adjusts for this by adding 10% to the data.

Housing presented special problems for our analysis. Unfortunately, there is no single source of housing data. We had to combine data from several sources and make some of our own estimates. Much of the historical data came from FW Dodge, the US Census, and the Oregon Association of Manufactured Homes. We used this to create our own balance sheet showing the inventory, new additions, losses, vacancies, and other factors necessary to predict housing construction. Housing was divided into seven categories ranging from high-rise apartments to manufactured homes.

Most of the information on roads in the models comes from ODOT. We adjusted ODOT's figures to account for small numbers of miscellaneous public roads. The road data were then divided up according to the type of surface. The forecast for road mileage is driven by the changes in the number of households and population densities of counties.

The model does not forecast private logging road mileage, but it does capture the aggregate use by this sector. This is done by comparing aggregate use to the sizes of timber harvests.

For BLM, USFS, and State Park and State Forestry Department roads, a different approach was used. From our base year of 1993, we assumed that state forest and park road miles will not change. For BLM and USFS gravel roads, we assumed that their mileage will be cut to 50% of the level reported to ODOT in 1993 by the year 2000.

Aggregate usage factors are important to the models. There is one factor for every category of construction. Most are single values that apply to all the years in the forecast. Others change from year to year, depending on economic conditions.

Since there are no published sources for usage factors, we had to make our own estimates. This was a very difficult task, because construction work is divided between many individual contractors. At most construction sites, no single person buys all the aggregate used. In addition, aggregate itself comes in different forms such as asphalt, concrete, precast products, and masonry sand. Those in the construction industry that we contacted could not readily tell us how much aggregate is used on their projects.

Mr. Joseph Gehlen, of Kramer Gehlen & Associates, volunteered his time to help us. Kramer Gehlen & Associates is a major structural and civil engineering consulting firm based in Vancouver, Wash. The firm works on a wide variety of large construction projects in Oregon and other parts of the west. Gehlen helped develop estimates for usage rates in typical structures.

Once we had factors for structures, we contacted people that specialize in site work. Before a building goes up, large amounts of aggregate go into site preparation. This includes sidewalks, entrance roads, sewers, water mains, and drainage areas.

Several construction companies then suggested we include extra amounts of aggregate for staging areas. A staging area is a place where contractors keep their heavy equipment and supplies on site. It is covered with a thick layer of crushed rock. This helps keep mud off equipment and supplies. It also prevents heavy equipment from sinking into the ground. Additional rock is used for temporary access roads. For large buildings, staging areas and temporary roads can be among the largest single uses of aggregate. The need for all this rock is highest in western Oregon, where construction activity extends into the wet winter months.

For roads, usage factors were used that vary depending upon the type of road, a county's population density, and its growth. When applied to 1993 county road mileage statistics, the estimate for aggregate consumption was within 5% of actual amount reported in the county road department survey.

Usage factors are a crucial part of the model, but they are highly variable. Two structures built for the same purpose and of the same size can use vastly different amounts of aggregate. In addition, if a building goes up on a brownfield site, it will use far less aggregate for site work than one built on vacant land. The factors in the models are broad averages. They can be changed to suit differences of opinion and unique circumstances.

Our models include several other categories of aggregate consumption. Railroad ballast is one of these. Ballast is the rock on top of which track is laid. New rock is added from time to time and it is a significant end use. Our forecast is based on the number of miles of main-line and short-line track in each county. Another important category is aggregate used on farms and ranches, and in other agricultural settings. We estimated this end use by factoring in the number, type, and average size of farms in each county.

We included three catchall categories for residential, nonresidential, and infrastructure construction. These account for repairs, maintenance, improvements, and other work not counted elsewhere in the models. We know that large amounts of remodeling and other types of construction are not captured in FW Dodge's data. These include everything from putting in of new patios by homeowners to having stores re-pave their parking lots. We forecast aggregate consumption for these by taking a percentage of both new construction and estimates of base level use in each county.

A miscellaneous category measures non-construction uses. It equals approximately 5% of statewide consumption. That percentage varies by county. Some non-construction uses are landscaping, jetties, hiking trails, stream reparations, cemeteries, golf courses, and landfills.

The models take into account technological improvements that yield efficiency gains. These are improvements in construction methods and materials that occur slowly over time. We used a very conservative 0.1% rate. That means, if there are no other changes from one year to the next, aggregate consumption will fall 0.1% because of new methods and materials.

We applied the 0.1% rate equally on all end uses except roads. An exception was made for roads because several road departments told us they are using or will be using lower grades of aggregate. They expect the growing scarcity of high-quality rock to lessen the life expectancy of pavement, and that will offset any technological improvements. Unlike other end-use categories, the majority of aggregate used on roads goes into maintenance rather than new construction.

Recycling is forecast by taking a percentage of total aggregate consumption. The percentages used are rough estimates by county, and they rise gradually each year. The difference between total consumption and recycling is the forecast for virgin aggregate use.

The results of the models were checked against actual county consumption data derived from the 1993 mining census. The comparisons were very close. Having actual data allowed us to refine the usage factors and recycling percentages used in the models. We were also helped by county road departments, ODOT, FW Dodge, studies for other parts of North America, reports from national aggregate producers, contacts in the construction industry, and various aggregate consumers in Oregon.

Chapter Two

Equations

Introduction

This chapter describes the structure and origin of 114 equations used in the construction aggregate models. Each equation forecasts a specific piece of information about a county for a given year. These equations can be replaced or modified by those wishing to change the model to suit their own needs.

The model was designed using data for Oregon, but its basic structure works for any state or region. To adapt the model to another region, some of the 114 equations factors and model adjustments must be re-estimated. Doing this requires the collection of population, income, road, housing, and construction data for the region being modeled. An estimate of aggregate consumption, based on a thorough accounting of local production, and regional imports and exports, must be made for a recent historical year. This is necessary so that aggregate usage rates and model adjustments can be re-set so they fit local circumstances. By using the model to forecast the recent historical year, modifications can be made. These will improve the accuracy of the model.

Definitions

The definitions of some of the terms used in this report appear below.

A **dependent variable** is a number or group of numbers that is calculated by an equation in a model. The value of a dependent variable varies with the assumptions used in the forecast. Some dependent variables are a series of numbers composed of both fixed values and variable ones. The fixed values are usually the part of the series that represents known history.

An example of a dependent variable is the number of houses built each year. This variable is a series of numbers. The values in the series depend upon assumptions used in the forecast for such things as population growth. If you change the population forecast, the forecast of housing construction (the dependent variable) will change. The historical portion of the series, however, is unaffected.

An **independent variable** is a number or group of numbers used to predict a dependent variable. In the example above, population growth is an independent variable that is used in an equation in the model to forecast housing construction.

Coefficients are numbers that are added to or multiplied by independent variables in equations. Coefficients weigh or convert independent variables into forecasts for a dependent variable.

A **regression** is a statistically estimated equation. It predicts the value of a dependent variable by mathematically manipulating one or more independent variables. The mathematical relationship between the dependent and independent variables is estimated using a regression analysis method. It relies on historical data for the variables.

For example, if we wanted to predict the number of phones in a county we may estimate a regression equation using the adult population as an independent variable. The regression equation may show that over the past ten years there has been an average of two phones for every adult in a county. The regression equation would predict the number of phones (dependent variable) as being equal to the number of adults (independent variable) times two (the coefficient of the independent variable). Regression equations can have several independent variables.

Fitted values are estimates of the dependent variable that are made by a regression. In the example above, the regression equation can be used to estimate the number of phones in a county in each of the past ten years. This series of estimates are fitted values. Since regression equations are almost never perfect predictors, the fitted values will differ from the actual values.

An $\mathbf{R^2}$ (or R-squared) is a measure of how close the fitted values match the actual values over the historical period used to estimate the regression equation. An R^2 ranges from zero to one. A value of 1.00 means that the fitted values of the regression equation perfectly match the actual data for the dependent values.

Correlation is a measure used to compare two variables. The correlation of two variables equals the square root of the R^2 for a regression between those variables.

Exogenous data are numbers that are fed into a forecast, but are not calculated internally in a model. Exogenous data usually drive forecasts. In the aggregate models, county population forecasts are exogenous data.

An **identity** equation is used in models to predict the values of dependent variables. Unlike a regression, however, an identity is explicitly stated. No regression analysis nor other statistical estimation is used to define the relationship between the dependent and independent variables. Identities usually express simple relationships that hold true under all circumstances throughout a forecast period.

A **T-statistic** is a measure of how much predictive value an independent variable has in a regression equation. Generally, a T-statistic greater than +1.50 or less than -1.50 indicates that a variable has significant predictive value.

Adjustment factors are used to improve the predictive value of regression equations. In the aggregate models, the same sets of regression equations are used for all 36 counties. Adjustment factors are used to correct for differences in the counties which are not accounted for by the independent variables.

Dams and Reservoirs

This series captures the costs of construction on dams and reservoirs used for flood control, hydroelectric power generation, and water supply. It is expressed in thousands of 1987 dollars. Dams and reservoirs are an important aggregate market. They constitute 0.8% of total aggregate consumption in the forecast.

The dam and reservoir series fluctuates widely. A base load of small projects that occur each year. At least one of these has happened in each county during the period from 1978 to 1994. Periodically, however, there are very large projects whose values overwhelm those of the small projects.

On Table Chapter Two -1 the average annual amounts spent on dam and reservoir projects are shown by counties for the 1978 to 1994 period. Western Oregon counties, which receive most of the state's rainfall, account for 83% of the spending. Spending is weakly correlated with county populations. The R^2 is 0.12 with a T-statistic of +2.2. Spending is not correlated with population growth, land area, or income growth. Spending per person averages $7 a year in eastern Oregon and $5 a year in western Oregon, however, the differences between individual counties are great. Using population as a predictor of spending proved to be unreliable.

As a time series, there are large variations in spending from one year to the next. Figure Chapter Two -1 is a graph of total construction spending recorded by FW Dodge on dams and reservoirs. In most years, between $1.0 Mn and $6.0 Mn are spent across the state. This fairly stable pattern is broken up by a few large projects that make the series unpredictable.

Lacking any practical alternatives, DOGAMI used the average rates of county dam and reservoir construction spending in 1978 to 1994 to make forecasts. This is shown in equation (1) below. Here construction is set to the historical average and then raised by 10/9 in order to compensate for the 90% coverage of the historical FW Dodge data. The results of this are used in equation (2) to forecast aggregate consumption for dams and reservoirs. The forecast can be easily changed. If a model user knows of a specific upcoming project, its value can be inserted in place of equation (1) at the appropriate year. In such cases, consideration should be given to lowering the forecasts for other years since equation (1) averages both high and low years. The user, by implicitly forecasting a high year, should lessen the average forecast for the remaining years.

The dam and reservoirs equations are:

(1) $DC_{C,T} = (10/9) * AVGDC_C$

(2) $ADC_{C,T} = DC_{C,T} * (AFDC + CPFDC) * TECH_T$

Where:

$DC_{C,T}$ is dam and reservoirs construction in thousands of 1987 dollars for a county in a specific future year.

$AVGDC_C$ is the county's annual average dam and reservoir construction in thousands of 1987 dollars for the years 1978 to 1994.

$ADC_{C,T}$ equals the tons of aggregate consumed in dam and reservoir construction for the county in the forecast year.

AFDC is the amount of aggregate directly used in Oregon for every thousand 1987 dollars worth of dam and reservoir construction. It equals about 23 tons for counties in western Oregon and 20 tons for counties in the eastern part of the state. Construction projects in western Oregon use more aggregate than the rest of the state because the region's annual rainfall is substantially greater.

CPFDC is the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon for every thousand 1987 dollars worth of dam and reservoir construction. It equals approximately 6.7 tons.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -1

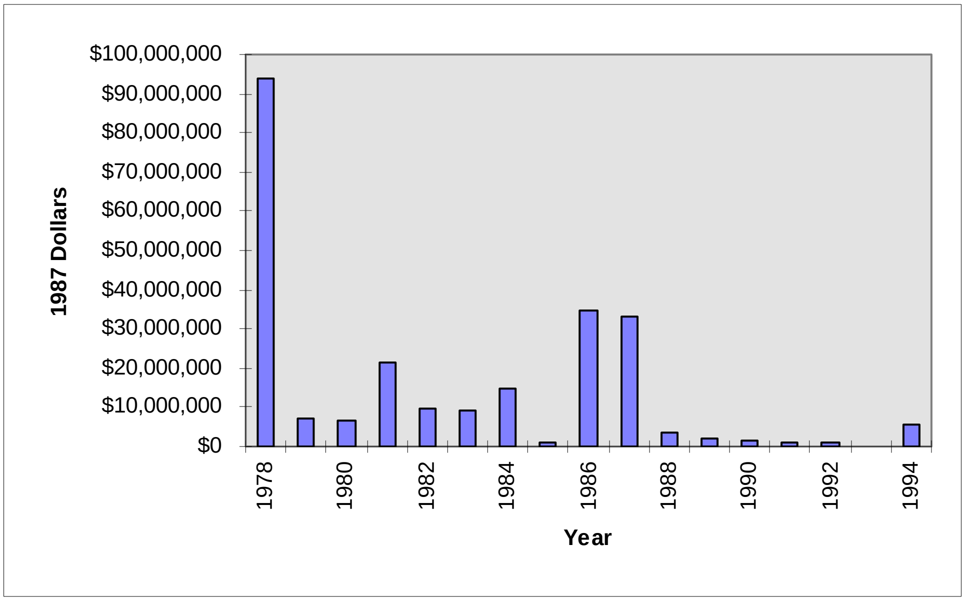
Dam and Reservoir Construction Spending by County
Annual Averages 1978 - 1994

County	***Thousands of 1987 $***
Baker	$22
Benton	$3
Clackamas	$276
Clatsop	$21
Columbia	$29
Coos	$66
Crook	$324
Curry	$47
Deschutes	$35
Douglas	$1,374
Gilliam	$3
Grant	$11
Harney	$11
Hood River	$54
Jackson	$6,849
Jefferson	$11
Josephine	$12
Klamath	$12
Lake	$6
Lane	$114
Lincoln	$66
Linn	$12
Malheur	$66
Marion	$74
Morrow	$1,070
Multnomah	$2,492
Polk	$65
Sherman	$37
Tillamook	$16
Umatilla	$741
Union	$6
Wallowa	$15
Wasco	$17
Washington	$335
Wheeler	$14
Yamhill	$196
Total	$14,502.00
Eastern Oregon	$2,390
Western Oregon	$12,102

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -1

Oregon Dam and Reservoir Construction Spending 1987 Dollars



Source: FW Dodge data modified by DOGAMI.

Detention Facilities

The detention facilities series includes the construction of jail, prison, juvenile detention, and related buildings. Construction is measured in thousands of square feet of building space. Aggregate consumption, however, includes not only the materials used in the buildings, but also that which is used in site preparation, staging areas, roads, parking lots, exterior grounds, perimeter walls, and other non-building features. For detention facilities these other uses are very significant. While this series is a minor part of the total building construction in the state, it can account for a large amount of aggregate consumption in rural counties. Statewide, 0.1% of total aggregate consumption is forecast to be used on detention facilities.

According to FW Dodge, from 1978 to 1993, an average of 94,300 square feet of detention facilities were built in Oregon. In 19 of the state's 36 counties there was no detention facility construction (see Table Chapter Two -2). Some counties and cities built facilities, but a large share of the construction was done by the state and Federal governments. In these cases, construction was driven not by local needs, but by regional demand. Because of this, detention facility construction on the county level is less sensitive to local population and economic factors than other building activities.

Statewide construction of detention facilities from 1978 to 1993 is shown in Figure Chapter Two -2. Over 90% of the construction during that 16 year period occurred after 1986. This building boom reflects the pent-up demand for new prisons and some replacement of obsolete facilities. Most of the construction can be traced to a handful of large projects. On average, four square feet of detention facility buildings have been constructed from 1978 to 1993 for every one person increase in the state's population of 18 to 64 year olds.

The statistical relationship between annual statewide construction and population growth is moderately significant. A regression shows an R^2 of 0.33 with a T-statistic of +2.6. The significance is greater when tested against the population growth of the youngest age group. The R^2 falls to 0.02 when the equation is run against the population growth of people 65 years of age and older.

Creating a county forecast equation was a difficult process because local needs for prisons does not correlate well with local prison construction. The best results came from equation (3). It is a regression of county data from Table Chapter Two -2 against changes in the number of 18 to 64 year olds. The R^2 is 0.20 with a statistically significant T-statistic of +2.9. With this equation, total detention facility construction would equal 49,457 square feet per year if there is no change in the population. Then another 1.9 square feet would be added for every increase in the number of 18 to 64 year olds in the state. For the 1978 to 1993 period, that equals 44,804 square feet a year for population growth.

Equation (3) includes two adjustment factors. The first is a county adjustment factor. It is a constant and it equals the difference between the historical actual and fitted results for equation (3). This factor raises the construction forecasts in counties which have added detention facilities in the 1978 to 1993 period. Detention facilities are more likely to be built in counties where such construction has taken place before. The second adjustment factor adds 30% to the forecast for the period up to 2005. This was inserted to account for an expected building cycle in detention facilities that will accommodate pent-up demand.

The detention facility equations are:

(3) $DETC_{C,T} = (10/9) * \{1.3738 + 0.001881 * [POP18_{C,T} - POP18_{C,T-1}] + CAFDET_C\} * YAFDET_T$

with $DETC_{C,T}$ having a minimum value of zero.

(4) $ADETC_{C,T} = DETC_{C,T} * (AFDETC_C + CPFDETC) * TECH_T$

Where:

$DETC_{C,T}$ is detention facility building construction in thousands of square feet for a county in a specific future year.

$POP18_{C,T}$ is the population of 18 to 64 year olds in the county for the specified year. The expression in equation (3) shows the change in the population of this age group from one year to the next.

$CAFDET_C$ is the county adjustment factor for detention building construction. It equals the difference between the historical actual and fitted results for this equation.

$YAFDET_T$ is an adjustment factor that equals 1.3 if the year being forecast is less than 2006 and 1.0 if it equals 2006 or greater.

$ADETC_{C,T}$ equals the tons of aggregate consumed in detention facility construction for the county in the forecast year.

$AFDETC_C$ is the amount of aggregate directly used in Oregon per thousand square feet of detention facility building construction. It equals 485 tons for counties in western Oregon and 445 tons for counties in the eastern part of the state where there is far less rainfall.

CPFDETC is the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon per thousand square feet of detention facility building construction. It equals approximately 30.3 tons.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -2

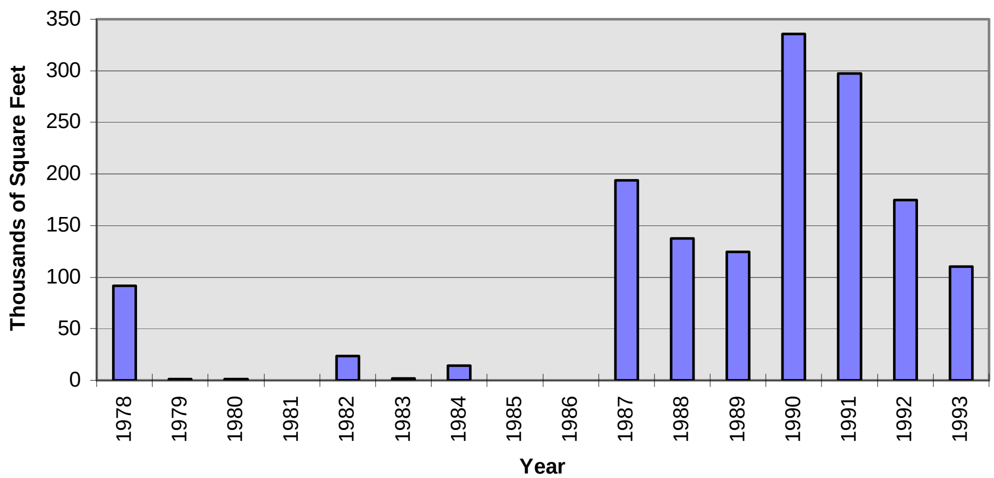
Detention Facility Building Construction by County
Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./Year*
Baker	3.9
Benton	0.0
Clackamas	5.0
Clatsop	0.0
Columbia	0.0
Coos	0.3
Crook	0.0
Curry	0.0
Deschutes	3.6
Douglas	0.0
Gilliam	0.0
Grant	0.0
Harney	0.0
Hood River	0.0
Jackson	5.1
Jefferson	0.9
Josephine	0.0
Klamath	3.6
Lake	0.0
Lane	2.2
Lincoln	4.5
Linn	3.1
Malheur	15.9
Marion	13.3
Morrow	0.0
Multnomah	24.3
Polk	0.0
Sherman	0.0
Tillamook	0.0
Umatilla	1.7
Union	0.4
Wallowa	0.0
Wasco	0.0
Washington	1.6
Wheeler	0.0
Yamhill	4.9
Total	94.3

Source: FW Dodge modified by DOGAMI.

Figure Chapter Two -2

Oregon Detention Facility Building Construction
Thousands of Square Feet



Source: FW Dodge data modified by DOGAMI.

Hospital and Health Care Buildings

The hospital and health care building series covers the construction of hospitals, clinics, nursing homes, medical offices, laboratories, and other health care buildings. The series is expressed in thousands of square feet of building floor space. In the forecast for Oregon, health care building construction constitutes 1.4% of total aggregate consumption. This includes aggregate used for site preparation, parking, access roads, construction staging areas, waste water systems, and other features related to erecting of health care buildings.

FW Dodge recorded construction of health care buildings in all but four counties for the period from 1978 to 1993. As can be seen from Table Chapter Two -3, health care building construction averaged 964,300 square feet a year in Oregon. The state's two most populous counties, Multnomah and Washington, accounted for 51% of the total even though they had 31% of the state's population and just 34% of the states population growth. Health care buildings tend to be located in population centers. Construction is highly correlated with population density.

Annual construction activity across the state is shown in Figure Chapter Two -3. Two years exhibited unusual spikes because of large projects, but the series is generally stable.

The health care series is highly correlates with various population measures. A regression against county population has an R^2 of 0.90 and a T-statistic of +17.7. An even higher R^2 of 0.95 was achieved in a regression with population density. When compared to the average change in population, the R^2 is 0.43 and the T-statistic is +5.1. Both of these are statistically significant. The correlations are lower, yet still significant, when just to 0-17 age group is used. The correlation is better with the 18-64 age group than with the over 64 age group even though the older group uses health care facilities more. This discrepancy happens because counties with high growth in 18-64 year olds also have high population densities. The 64 and over groups are more likely to dominate in rural counties. Population density is highly correlated with hospital construction.

DOGAMI tested many equations. The goal was to create an equation that factored in population size, growth, and density while avoiding problems of multicollinearity. Population size is important because it helps explain the amount building construction needed to replace and maintain a county's existing health care infrastructure. Population growth explains the expanding county health care needs from new residents. Population density factors in the effect of health care clustering around urban areas.

Equation (5) worked best. Its R^2 is 0.58 while the two independent variables are not correlated with one another. The dependent variable is a transformation of the health car series. The series was divided by county populations. The equation forecasts how much construction will take place per person living in a county. Using this transformation lowers the R^2 , but produces good results because it takes into account the populations of counties. The mean absolute deviation of the construction forecast works out to just 14%.

There are two independent variables in equation (5). The first measures population growth. It has a significant T-statistic of +4.5. The second variable estimates the population density of residents over 64 years of age who live in non-rural areas. Its T-statistic is +4.8. This variable captures to effect that high, concentrated populations of elderly residents have on the location of health care buildings.

Equation (6) calculates the aggregate usage rate. For most counties, it is a constant. For counties with more than 100 households per square mile, the usage rate is a variable. Usage rates are lower in densely populated counties because high land costs and more public transportation reduce the amount of aggregate needed to accommodate cars. Currently only two counties have household densities over 100. The highest is Multnomah County. Its usage rate is about three tons per thousand square feet lower because of the county's density.

The hospital and health care building equations are:

$$(5)\ (HC_{C,T} / POP_{C,T}) = (10/9) * \{-0.00678 + 0.006895 * [POP_{C,T} / POP_{C,T-1}] + 0.0000027255 * [POP65_{C,T} * URB_{C,T}] / AREA_{C}\}$$

with $(HC_{C,T} / POP_{C,T})$ having a minimum value of zero.

(6) $TAFH_{C,T} = AFHC_C + CPFHC - \{\text{if } HHDEN_{C,T} < 100 \text{ then } 0 \text{ else } 15 * (HHDEN_{C,T} - 100) / 1900\}$

(7) $AH_{C,T} = TAFH_{C,T} * HC_{C,T} * TECH_T$

Where:

$HC_{C,T}$ is hospital and health care building construction in thousands of square feet for a county in a specific future year.

$POP_{C,T}$ is the total population of a county for the specified year.

$POP65_{C,T}$ is the county's population of 65 year olds and up for a given year.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

$AREA_{C}$ equals the land area of a county in square miles.

$TAFH_{C,T}$ is the amount of aggregate used in county per thousand square feet of health care building construction. This is a constant for counties with less than 100 households per square mile.

$AFHC_{C}$ is the amount of aggregate directly used in Oregon per thousand square feet of health care building construction. It equals 417 tons for counties in western Oregon and 377 tons for counties in the drier, eastern part of the state.

CPFHC is the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon per thousand square feet of health care building construction. It equals approximately 12.1 tons.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$TECH_{T}$ is the statewide technology factor for the forecast year.

Table Chapter Two -3

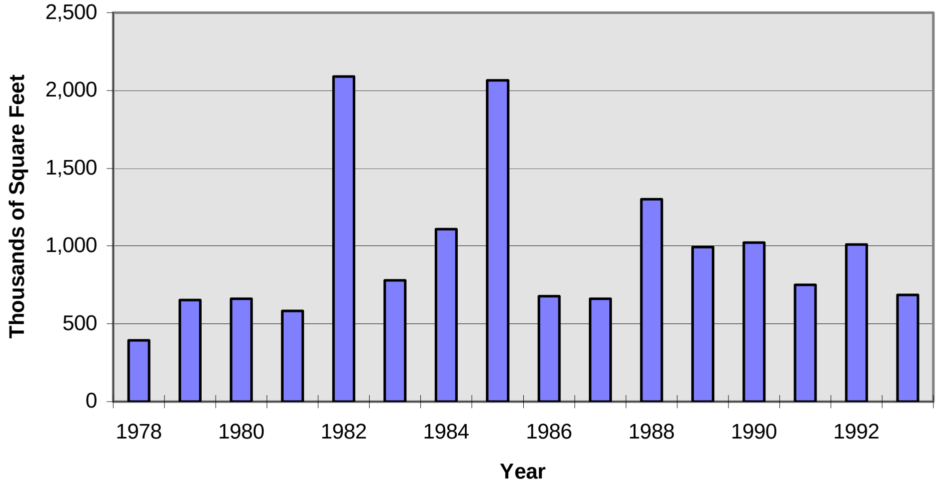
Hospital & Health Care Building Construction by County
Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./Year*
Baker	3.4
Benton	18.3
Clackamas	75.4
Clatsop	3.3
Columbia	6.7
Coos	9.3
Crook	2.1
Curry	1.1
Deschutes	29.7
Douglas	17.3
Gilliam	0.1
Grant	0.1
Harney	0.0
Hood River	5.0
Jackson	45.7
Jefferson	4.5
Josephine	10.1
Klamath	12.4
Lake	0.6
Lane	69.0
Lincoln	10.6
Linn	13.8
Malheur	6.7
Marion	81.3
Morrow	0.4
Multnomah	353.7
Polk	6.9
Sherman	0.0
Tillamook	2.7
Umatilla	10.6
Union	3.2
Wallowa	0.0
Wasco	9.9
Washington	136.5
Wheeler	0.0
Yamhill	14.1
State	964.3

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -3

Oregon Hospital & Health Care Building Construction
Thousands of Square Feet



Source: FW Dodge data modified by DOGAMI.

Hotels and Motels

The hotels and motels series measures the floor space, in thousands of square feet, of hotels and motels built each year. It includes most, but not all, types of travelers' lodging. Hotels and motels make up about 0.5% of the aggregate consumption forecast for 2001 to 2050 in Oregon. This includes all the aggregate used in new hotel and motel construction.

For the period from 1978 to 1993, 7,041,300 square feet of hotel and motel floor space was built in Oregon (see Table Chapter Two -4). Construction was concentrated in counties with urban areas and resort communities. The Portland area counties made up 45% of the total hotel and motel construction. Six other counties added over 250,000 square feet. They are Clatsop, Deschutes, Jackson, Lane, Lincoln, and Marion Counties. No construction was reported in ten counties.

Figure Chapter Two -4 shows the annual amounts of hotel and motel construction for the state. It follows a cyclical pattern that is evidence of a periods of over building followed by slowdowns. Because of the cyclical nature of the data, the 16-year time period in Figure Chapter Two -4 is too short to identify any clear relationships between it and statewide economic data.

The data series of total hotel and motel construction by county does correlate well with county economic data. The R^2 using real personal income as an independent variable is 0.89. With a T-statistic of 16.2, it is highly significant. Slightly better results are achieved using the number of households. Versus population, the R^2 is 0.87. Population density produces a lower R^2 of 0.80. That happens because counties with attractive vacation areas tend to have low population densities.

DOGAMI developed an equation which takes into consideration the two primary drivers of hotel and motel construction. They are population and the county's standing as a vacation destination. Equation (8) does this. Its R^2 is 0.92. The T-statistic for the population variable's coefficient is 18.2. The vacation home variable's T-statistic is 4.3. Both are significant. The vacation variable equals the change in the number of vacation, recreational, and seasonal housing units in the county.

Equation (9) calculates the aggregate usage rate. This rate is the same for all counties with densities under 100 households per square mile. For others, the usage rate is slightly less. This downward adjustment is made for densely populated counties where high-rise hotels are more common. These require slightly less aggregate per square foot of occupied space.

The hotel and motel building construction equations are:

(8) $HOTC_{C,T} = (10/9) * -3.63376 + 0.000178 * POP_{C,T} + 0.053918 * [VU_{C,T} - VU_{C,T-1}] + CAFHOT_C$

with $HOTC_{C,T}$ having a minimum value of zero.

(9) $TAFHOT_{C,T} = AFHOT_C + CPFHOT - \{\text{if } HHDEN_{C,T} < 100 \text{ then } 0 \text{ else } 30 * (HHDEN_{C,T} - 100) / 1900\}$

(10) $AHOT_{C,T} = TAFHOT_{C,T} * HOTC_{C,T} * TECH_T$

Where:

$HOTC_{C,T}$ is hotel and motel building construction in thousands of square feet for a county in a specific future year.

$POP_{C,T}$ is the total population of a county for the specified year.

$VU_{C,T}$ is the number of vacation, recreational, and seasonal housing units in a given county. This includes both occupied and unoccupied housing.

$CAFHOT_C$ is the county's adjustment factor for hotel and motel building construction. It equals the difference between the historical actual and fitted results for this equation.

$TAFHOT_{C,T}$ is the amount of aggregate used in a county per thousand square feet of hotel and motel building construction. This is a constant for counties with less than 100 households per square mile.

$AFHOT_C$ is the amount of aggregate directly used in Oregon per thousand square feet of hotel and motel building construction. It equals 340 tons for counties in western Oregon and 300 tons for counties in the eastern part of the state. Construction projects in western Oregon use more aggregate than the rest of the state because the region's annual rainfall is substantially greater.

CPFHC is the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon per thousand square feet of hotel and motel building construction. It equals approximately 18.5 tons.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -4

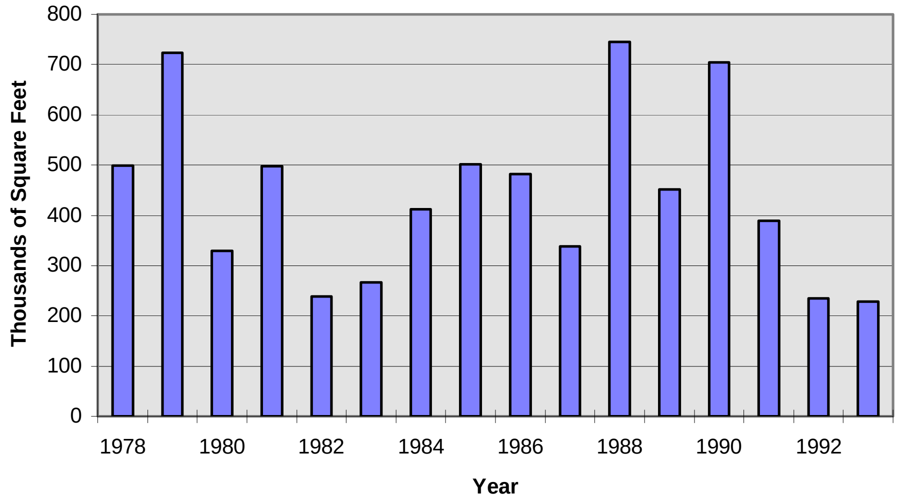
Hotel and Motel Building Construction by County
Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./Year*
Baker	0.0
Benton	7.6
Clackamas	44.4
Clatsop	23.2
Columbia	0.0
Coos	4.6
Crook	1.6
Curry	7.0
Deschutes	25.8
Douglas	12.5
Gilliam	0.0
Grant	0.1
Harney	2.7
Hood River	4.7
Jackson	32.1
Jefferson	0.9
Josephine	11.1
Klamath	4.1
Lake	0.0
Lane	31.7
Lincoln	23.3
Linn	1.5
Malheur	0.2
Marion	26.2
Morrow	0.0
Multnomah	118.3
Polk	0.0
Sherman	0.0
Tillamook	8.9
Umatilla	5.9
Union	0.0
Wallowa	0.0
Wasco	0.5
Washington	35.4
Wheeler	0.0
Yamhill	5.7
Total	440.1

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -4

Oregon Hotel and Motel Building Construction
Thousands of Square Feet



Source: FW Dodge data modified by DOGAMI.

Manufacturing Plants and Labs

The manufacturing plants and labs series includes all manufacturing production facilities and laboratories. It excludes all, but incidental, warehouse and office space. The series is in thousands of square feet of building space. Besides building space, substantial amounts of aggregate are in this type of construction for parking lots, outdoor storage areas, truck loading facilities, access roads, waste treatment areas, and site preparation. In Oregon, common varieties of manufacturers are lumber mills, ship yards, food processors, electronics plants, and paper mills. In the state forecast, this series contributed 1.8% to total aggregate consumption.

Manufacturing buildings were constructed in 33 of Oregon's 36 counties between 1978 to 1993. The data are shown on Table Chapter Two -5. According to FW Dodge, Oregon added 22,294,500 square feet of manufacturing buildings. Ninety percent of the floor space was built in western Oregon and 58% went in around the Portland metropolitan area.

Annual data for the state shows the rate of construction declined over time (see Figure Chapter Two -5). This is attributable to changes in the forest products industry. Reductions in logging, large productivity gains in manufacturing, and an ample supply of vacant facilities have taken a toll on new plant construction. Since 1993, it is believed that construction has risen sharply because of new electronics plants.

County manufacturing plant data is highly correlated with population and income variables. In a regression equation with population as the independent variable, the R^2 is 0.63 with a T-statistic of 7.6. Results improve when the change in the working age population is used. The R^2 is 0.90 with a T-statistic of 17.4. What this says is that counties who have seen their populations of 18 to 64 year olds rise substantially also saw most of the additions of new manufacturing space. The R^2 in an equation using real personal income is 0.67. The R^2 rises to 0.88 when the change in real personal income is used. The T-statistic goes up to 15.6. This regression equation was selected for the model and is shown below as equation (11).

An important feature of equation (11) is the county adjustment factor. It helps explain differences between counties that are not captured in the personal income data. Counties, such as Washington, have seen more manufacturing construction than their gains in personal income levels would otherwise suggest. Others, like Deschutes and Clackamas Counties, have seen the opposite. Their income levels outpaced growth in manufacturing space.

The manufacturing plant and lab building construction equations are:

(11) $MANFC_{C,T} = (10/9) * -2.001 + 0.001758 * [PI_{C,T} - PI_{C,T-1}] + CAFMANF_C$

with $MANFC_{C,T}$ having a minimum value of zero.

(12) $TAFMANF_{C,T} = AFMANF_C + CPFMANF - \{\text{if } HHDEN_{C,T} < 100 \text{ then } 0 \text{ else } 20 * (HHDEN_{C,T} - 100) / 1900\}$

(13) $AMANF_{C,T} = TAFMANF_{C,T} * MANFC_{C,T} * TECH_T$

Where:

$MANFC_{C,T}$ is manufacturing plant and lab building construction in thousands of square feet for a county in a specific future year.

$PI_{C,T}$ is the total real personal income in a county for a specified year. It is in terms of thousands of 1987 dollars.

$CAFMANF_C$ is the county adjustment factor for manufacturing plant and lab building construction. It equals the difference between the historical actual and fitted results for this equation.

$CAFHOT_C$ is the county's adjustment factor for hotel and motel building construction. It equals the difference between the historical actual and fitted results for this equation.

$TAFMANF_{C,T}$ is the amount of aggregate used in a county for every thousand square feet of manufacturing floor space that is built. This is a constant for counties with less than 100 households per square mile. For others is lower depending on the density of the area.

$AFMANF_C$ is the amount of aggregate directly used in Oregon per thousand square feet of manufacturing plant and lab floor space that is built. It equals 365 tons in western Oregon counties where contractors have to contend with long periods of wet weather. It is 325 tons for counties in the drier eastern and central parts of Oregon.

CPFMANF is the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon per thousand square feet of manufacturing plant and lab floor space construction. It equals 35 tons.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -5

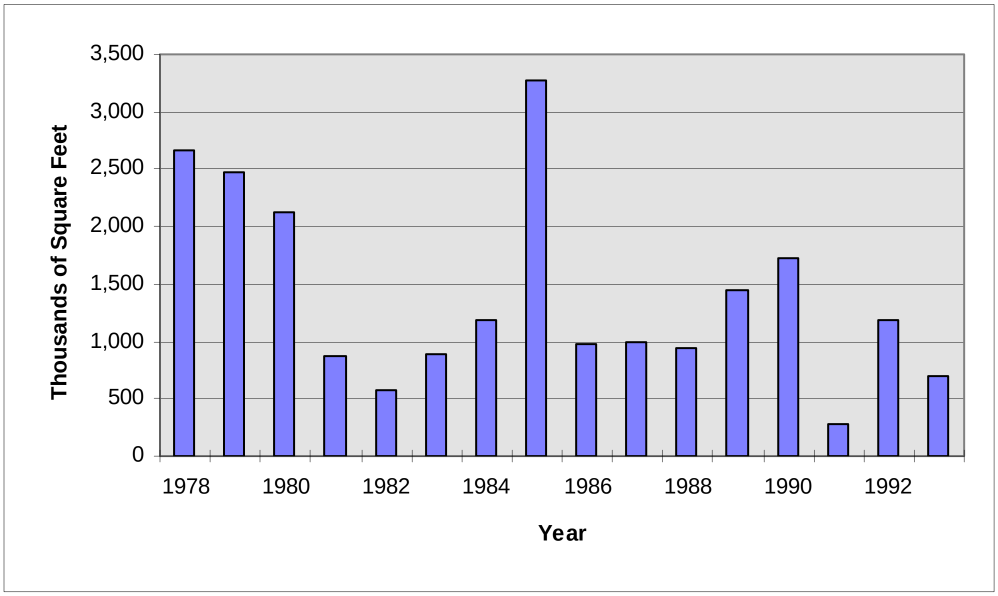
Manufacturing Plant and Lab Construction by County
Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./ Year*
Baker	6.3
Benton	39.1
Clackamas	159.9
Clatsop	12.1
Columbia	15.0
Coos	6.0
Crook	1.0
Curry	1.9
Deschutes	21.3
Douglas	42.2
Gilliam	0.0
Grant	22.0
Harney	15.0
Hood River	4.9
Jackson	34.6
Jefferson	8.9
Josephine	4.9
Klamath	15.7
Lake	1.9
Lane	88.2
Lincoln	5.2
Linn	38.5
Malheur	6.7
Marion	88.6
Morrow	8.9
Multnomah	239.9
Polk	4.9
Sherman	0.0
Tillamook	18.2
Umatilla	29.0
Union	3.0
Wallowa	0.4
Wasco	4.3
Washington	412.8
Wheeler	0.0
Yamhill	32.3
Total	1,393.4

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -5

Oregon Manufacturing Plants and Labs Construction Thousands of Square Feet



Source: FW Dodge data modified by DOGAMI.

Office Buildings

Office buildings include structures that are designed mostly to be used as offices, banks, and financial institutions. The model splits office data according to building heights. High-rise office buildings are those that are at least four stories high. DOGAMI's forecast shows high-rise offices accounting for 0.5% of the state's future aggregate consumption. Low-rise office buildings will consume 1.7%.

FW Dodge reported 32,627,600 square feet of office building construction in Oregon from 1978 to 1993. High-rise offices composed 39% of the total space.

Office building construction is not evenly distributed according to population growth. Instead, it concentrates around population centers and areas where incomes are high. In Oregon, an average of 86 square feet of office building space was added between 1978 and 1993 for every new 18 to 64 year old in the state. In eastern and central Oregon, only 30 square feet were added. In Multnomah County, which is a high income urban area, 262 square feet were built for each new 18 to 64 year old.

Table Chapter Two -6 is a list of annual average office building construction by county. The largely rural counties of eastern and central Oregon accounted for just 3% of the state's total office construction. Multnomah, Clackamas, and Washington Counties, which make up the Portland metropolitan area, made up 74% of the office space built from 1978 to 1993. Those counties also were the sites for 90% of the high-rise office space construction.

Office construction is cyclical. Half of the office space built from 1978 to 1993 went up in the first five years of that period (see Figure Chapter Two -6).

The county office construction data series is correlated with population, income, and density data. The R^2 using population as an independent variable is 0.88 with a T-statistic of 16.2. Slightly better results are achieved using the population of 18-64 year olds. In this case the R^2 rises to 0.89. The correlations are stronger when regressions are run against income and density variables. The R^2 using household density as the independent variable is 0.91 with a T-statistic of 18.1. With real personal income the R^2 goes up to 0.94. The T-statistic rises to 22.8.

DOGAMI tested many different equations. The best results were achieved with an equation that forecasts total office space construction. It has two independent variables and an R^2 of 0.99. The first variable measures the non-rural population density of 18 to 64 year olds. It explains the impact urbanized working age populations have of the demand for new office buildings. This variable's T-statistic is 18.5. The second variable captures the effect of real income growth. It equals the change in a county's total real personal income. Its T-statistic is 9.4. There is some multicollinearity between the two independent variables, but it is fairly modest. When regressed against one another the result is an R^2 of 0.46.

This equation for total office construction is embedded in DOGAMI's models in two equations. Equation (14), which is shown below, forecasts high-rise office building construction. Equation (15) forecasts low-rise construction.

The split between high and low-rise offices is based on historical data that appears here in Table Chapter Two -6. Only five counties reported any high-rise office construction from 1978 to 1993. These counties had high percentages of non-rural populations and high household densities. Since so few counties reported high-rise construction, a regression analysis was impractical for developing a forecasting equation. A simple mathematical approach was used instead. With this method it is assumed that only counties with more than 25 households per square mile and 85% of their population living in non-rural areas would have high-rise office building construction. The percent of high-rise construction would match a formula that depends on the non-rural household density of the county. A graph of this formula is shown in Figure Chapter Two -7. The formula is part of equation (15).

The office building construction equations are:

(14) $HROC_{C,T} = (10/9) * \{ -10.6511 + 0.7965 * POP18_{C,T} * URB_{C,T} / AREA_C + 0.001402 * [PI_{C,T} - PI_{C,T-1}] + CAFO_C - LROC_{C,T} \}$

with $HROC_{C,T}$ having a minimum value of zero.

(15) $LROC_{C,T} = (10/9) * [$ if $URB_{C,T} > 0.85$ and $HHDEN_{C,T} > 25$ then $1 - \{$ if $(URB_{C,T} * HHDEN_{C,T}) < 750, 0.05 + 0.00081 * URB_{C,T} * HHDEN_{C,T} , 0.6575 + 0.002 * ((URB_{C,T} * HHDEN_{C,T})-750) \} , 1] * \{ -10.6511 + 0.7965 * POP18_{C,T} * URB_{C,T} / AREA_C + 0.001402 * [PI_{C,T} - PI_{C,T-1}] + CAFO_C \}$

with $LROC_{C,T}$ having a minimum value of zero.

(16) $TAFHRO_{C,T} = AFHRO_C + CPFHRO - \{$if $HHDEN_{C,T} < 100$ then 0 else $10 * (HHDEN_{C,T} - 100) / 1900\}$

(17) $TAFLRO_{C,T} = AFLRO_C + CPFLRO - \{$if $HHDEN_{C,T} < 100$ then 0 else $20 * (HHDEN_{C,T} - 100) / 1900\}$

(18) $AHRO_{C,T} = TAFHRO_{C,T} * HROC_{C,T} * TECH_T$

(19) $ALRO_{C,T} = TAFLRO_{C,T} * LROC_{C,T} * TECH_T$

Where:

$HROC_{C,T}$ is high-rise office building construction in thousands of square feet for a county in a specific future year.

$POP18_{C,T}$ is the population of 18 to 64 year olds in the county for the specified year. The expression in equation (3) shows the change in the population of this age group from one year to the next.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

$AREA_C$ equals the land area of a county in square miles.

$PI_{C,T}$ is the total real personal income in a county for a specified year. It is in terms of thousands of 1987 dollars.

$CAFO_C$ is the county adjustment factor for total office building construction. It equals the difference between the historical actual and fitted results for the part of the equation that forecasts the sum of high and low-rise office building construction.

$LROC_{C,T}$ is low-rise office building construction in thousands of square feet for a county in a specific future year.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$TAFHRO_{C,T}$ is the amount of aggregate used in a county for every thousand square feet of high-rise office floor space built. This is a constant for counties with less than 100 households per square mile. For others is lower depending on the density of the area.

$AFHRO_C$ is the amount of aggregate directly used in Oregon per thousand square feet of high-rise office floor space that is built. It equals 210 tons in western Oregon counties where contractors have to contend with long periods of wet weather. It is 190 tons for counties in the drier eastern and central parts of Oregon.

CPFHRO is the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon per thousand square feet of high-rise office space construction. It equals about 31 tons.

$TAFLRO_{C,T}$ equals the tons of aggregate consumed for every 1,000 square feet of low-rise office building constructed. This number is constant except for densely populated counties where it falls slightly as the density rises.

$AFLRO_C$ is the amount of aggregate directly used in Oregon per thousand square feet of low-rise office floor space built. For western Oregon, it equals 345 tons. In drier eastern and central Oregon, it is 305 tons.

CPFLRO is the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon per thousand square feet of low-rise office space construction. It equals about 21 tons.

$AHRO_{C,T}$ is the amount of aggregate consumed for high-rise office construction in a county for a specific year.

$TECH_T$ is the statewide technology factor for the forecast year.

$ALRO_{C,T}$ is the amount of aggregate consumed for low-rise office construction in a county for a specific year.

Table Chapter Two -6

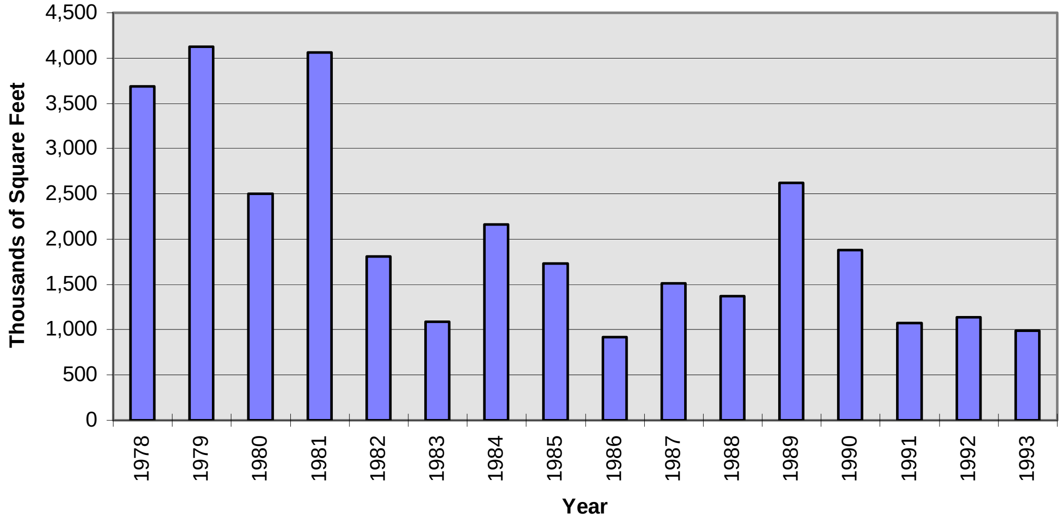
Office Building Construction by County
Annual Averages 1978 - 1993

County	Thousands of Sq. Ft./Year	Portion That is High-rise
Baker	1.1	0%
Benton	18.0	0%
Clackamas	271.5	33%
Clatsop	7.0	0%
Columbia	9.9	0%
Coos	4.5	0%
Crook	2.1	0%
Curry	4.8	0%
Deschutes	32.8	0%
Douglas	15.5	0%
Gilliam	0.2	0%
Grant	1.2	0%
Harney	0.0	0%
Hood River	2.6	0%
Jackson	42.3	0%
Jefferson	1.1	0%
Josephine	7.7	0%
Klamath	9.5	0%
Lake	0.0	0%
Lane	135.3	23%
Lincoln	10.6	0%
Linn	20.9	0%
Malheur	0.8	0%
Marion	162.8	28%
Morrow	2.4	0%
Multnomah	843.9	63%
Polk	2.9	0%
Sherman	0.0	0%
Tillamook	2.8	0%
Umatilla	8.3	0%
Union	4.7	0%
Wallowa	0.7	0%
Wasco	5.3	0%
Washington	400.2	23%
Wheeler	0.0	0%
Yamhill	8.6	0%
Total	2,042.0	39%

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -6

Oregon Office Building Construction
Thousands of Square Feet



Source: FW Dodge data modified by DOGAMI.

Table Chapter Two -7

High-rise Office Space Construction for Counties
With High Non-Rural Household Densities

County (Ranked by Density)	*1990 Density Non-Rural[1] Households Per Square Mile*	*Non-Rural Share of Total 1990 Population*	*1978 - 1993 Office Construction % High-rise*
Multnomah	550	98.8%	63%
Washington	154	93.2%	23%
Marion	63	88.9%	28%
Clackamas	49	88.1%	33%
Benton	33	84.8%	0%
Yamhill	23	74.0%	0%
Lane	21	85.5%	23%
Polk	19	77.1%	0%
Jackson	17	82.4%	0%
Columbia	14	67.7%	0%

Sources: DOGAMI, FW Dodge, and 1990 US Census block data.

[1] A non-rural household is one that lives in a census block where there is more than one family for every ten acres.

Figure Chapter Two -7

High-Rise as a Percentage of Total Office Building Construction Versus Urban Household Density

Source: DOGAMI estimate.

Retail Buildings

The retail building series includes the construction of stores, auto repair shops, restaurants, bars, and shopping centers. The series is expressed in thousands of square feet of indoor space. Besides the buildings themselves, large quantities of aggregate are used in retail construction for parking areas, landscaping, sidewalks, site work, access roads, staging areas, common areas, underground utilities, and other features. Retail building construction makes up 3.7% of the total aggregate consumption forecast for Oregon.

From 1978 to 1993, according to FW Dodge, retail building construction averaged 2,660,700 square feet a year in Oregon. No construction was reported in four counties. Two-thirds of the retail building construction took place in the state's five most populous counties. A county breakdown of retail construction appears on Table Chapter Two -8.

Retail buildings are constructed either to replace old structures or to satisfy new retail demand. While replacement construction is related to the size of a county's retail market, the demand for space for new retail demand is sensitive to real income growth. Because of this retail building construction follows a cyclical pattern. This is reflected in the data for Oregon shown in Figure Chapter Two -8.

Retail building construction is highly correlated to both the levels and growth rates of incomes and populations. In a regression using the number of households as the independent variable, the R^2 is 0.79. With a T-statistic of 11.4, this result is significant. When the construction series is regressed against the change in households, the R^2 rises substantially to 0.94. A regression using the change in real personal income as an independent variable shows an R^2 of 0.97 and a highly significant T-statistic of 30.9.

Many different forecasting equations were tested for the model. Three factors proved to explain most of the retail building construction in counties. The number of households is the first of these. It captures the impact of replacement construction because it is an indicator of the size of retail activity occurs in a county. The second factor, which tied to demand for new retail space, is the change in real income. The third factor is household density. The more urbanized a county is, the more real income growth is needed before retail building construction takes place.

Combining all three factors into one equation was impractical because of multicollinearity. To get around this, a two step process was used. It began with an estimate of replacement construction as it relates to the number of households. A regression was run with real income growth and the number of households as independent variables. This equation had an R^2 of 0.98 with T-statistics of +15.9 and +3.8, respectively.

The coefficient of the number of households indicated that for every 1,000 existing households in a county, 531 square feet of retail buildings were constructed each year to replace old structures. For the 1978 to 1993 period in Oregon, such construction amounts to 21% of the total. The coefficient was used to estimate the amount of retail space construction due to growth. A ratio of the change in real personal income to growth based construction was then calculated for each county. These ratios simply state how much real personal income growth occurred for every square foot of retail space built (other than replacement construction).

The ratios are sensitive to the degree of urbanization of the counties. The 18 most densely populated counties have a ratio of $401 (1987 dollars). In other words, there was $401 of real income growth for every square foot of retail space added due to growth between 1978 and 1993. Those counties had an average density of 34.14 households per square mile. At the extreme was Multnomah County. Its ratio was $474.75 and it density was 544.64 households per square mile. For the 18 least densely populated counties, the ratio was $321. The least densely populated counties had an average of 2.07 households per square mile.

Figure Chapter Two -9 shows the relationship between the ratio and household density. It was derived from the analysis above where data on groups of counties were clustered. This relationship was used in equation (20). It considers all three factors necessary to forecast retail construction. A regression based on all 36 counties was not used because the ratios of four counties were incalculable because they reported no construction. A few others, with small levels of construction, had unrepresentative ratios that were deemed to be unreliable.

The mean absolute deviation of the actual versus fitted values of equation (20) equals 15%. The retail building construction equations are:

(20) $RETC_{C,T}$ = (10/9) * { if $HHDEN_{C,T}$ < 34.14 then (0.000531 * $HH_{C,T}$) + [if ($PI_{C,T}$ - $PI_{C,T-1}$) < 0 then 0 else ($PI_{C,T}$ - $PI_{C,T-1}$) / (315.84 + 2.494543 * $HHDEN_{C,T}$)] else (0.000531 * $HH_{C,T}$) + [if ($PI_{C,T}$ - $PI_{C,T-1}$) < 0 then 0 else ($PI_{C,T}$ - $PI_{C,T-1}$) / (401 + 0.144466 * ($HHDEN_{C,T}$ - 34.14))] + $CAFRET_C$ }

with $RETC_{C,T}$ having a minimum value of zero.

(21) $TAFRET_{C,T}$ = $AFRET_C$ + CPFRET - {if $HHDEN_{C,T}$ < 100 then 0 else 35 * ($HHDEN_{C,T}$ - 100) / 1900}

(22) $ARET_{C,T}$ = $TAFRET_{C,T}$ * $RETC_{C,T}$ * $TECH_T$

Where:

$RETC_{C,T}$ is retail building construction in thousands of square feet for a county in a specific future year.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$HH_{C,T}$. equals the number of households living in a specific county in a given year.

$PI_{C,T}$ is the total real personal income in a county for a specified year. It is in terms of thousands of 1987 dollars.

$CAFRET_C$ is the county adjustment factor for retail building construction. It equals the difference between the historical actual and fitted results for this equation.

$TAFRET_{C,T}$ is the amount of aggregate used in a county for every thousand square feet of retail floor space built. This is a constant for counties with less than 100 households per square mile. For others is lower depending on the density of the area.

$AFRET_C$ is the amount of aggregate directly used in Oregon per thousand square feet of retail building floor space that is built. It equals 379.1 tons in central and eastern Oregon. It is 419.1 in western Oregon where the climate is much wetter.

CPFRET is the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon per 1,000 square feet of retail building space construction. It equals about 30 tons.

$TAFLRO_{C,T}$ equals the tons of aggregate consumed for every 1,000 square feet of low-rise office building constructed. This number is constant except for densely populated counties where it falls slightly as the density rises.

$AFLRO_C$ is the amount of aggregate directly used in Oregon per thousand square feet of low-rise office floor space built. For western Oregon, it equals 345 tons. In drier eastern and central Oregon, it is 305 tons.

CPFLRO is the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon per thousand square feet of low-rise office space construction. It equals about 21 tons.

$ARET_{C,T}$ is the amount of aggregate used in retail building construction in a county for a specific year.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -8

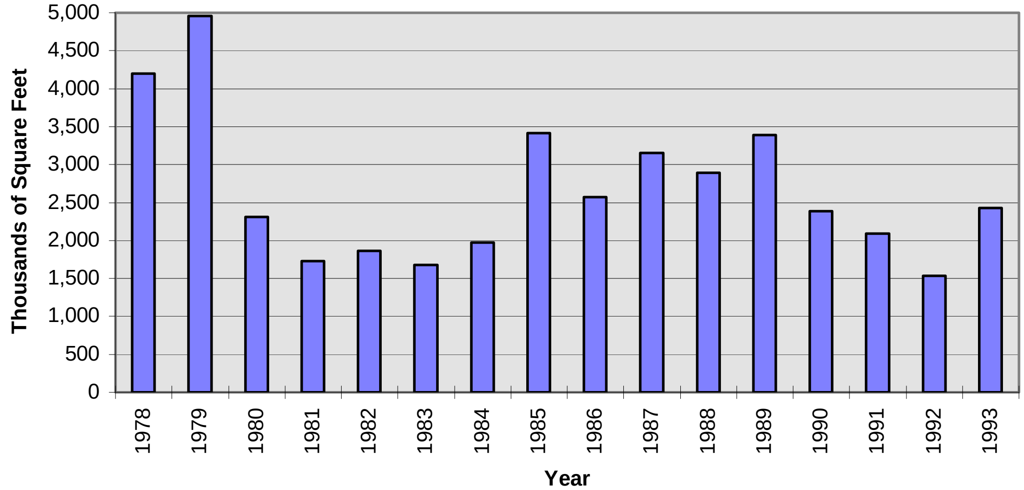
Retail Building Construction by County
Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./ Year*
Baker	3.2
Benton	43.1
Clackamas	402.6
Clatsop	33.2
Columbia	8.3
Coos	29.6
Crook	15.8
Curry	23.2
Deschutes	109.6
Douglas	73.8
Gilliam	0.0
Grant	0.0
Harney	3.1
Hood River	10.8
Jackson	200.7
Jefferson	2.1
Josephine	35.6
Klamath	40.1
Lake	1.8
Lane	225.6
Lincoln	51.8
Linn	80.6
Malheur	12.6
Marion	248.0
Morrow	2.3
Multnomah	419.9
Polk	24.9
Sherman	0.0
Tillamook	7.3
Umatilla	17.3
Union	10.2
Wallowa	0.7
Wasco	15.5
Washington	455.8
Wheeler	0.0
Yamhill	51.8
Total	2,660.7

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -8

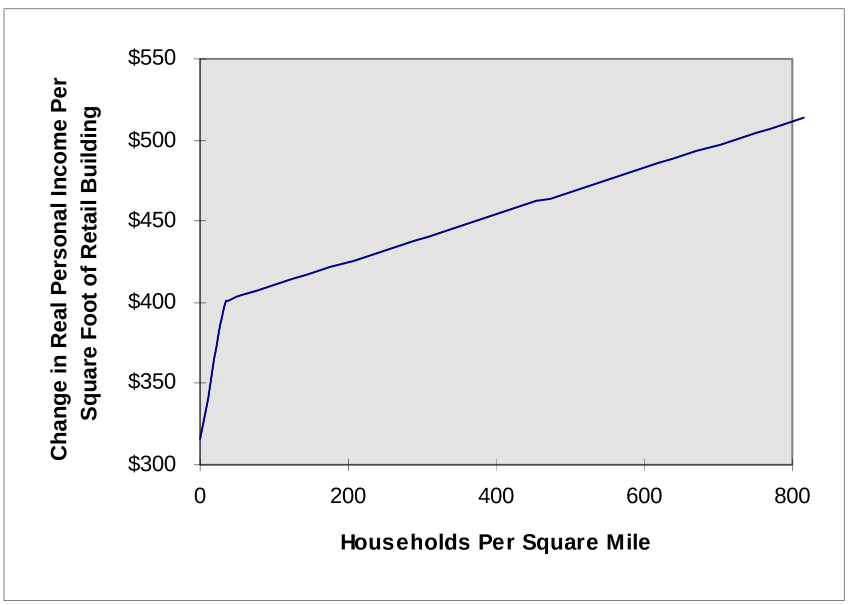
Oregon Retail Building Construction Thousands of Square Feet



Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -9

Change in Real Personal Income Per Square Foot of New Retail Building Construction Versus Household Density



Source: DOGAMI estimate.

School Buildings

The school series includes all the building construction for schools, colleges, universities, vocational centers, pre-schools, and dormitories. The series is reported in thousands of square feet of building space. Besides direct uses in buildings, substantial amounts of aggregate are used for such things as site preparation, utilities, outdoor recreational areas, parking lots, sidewalks, outdoor lighting, and swimming pools. In total, 1.0% of the aggregate consumption forecast for Oregon will go into school construction.

Table Chapter Two -9 shows the historical school building construction activity by counties. According to FW Dodge, 15,316,400 square feet of school buildings were contracted for in Oregon from 1978 to 1993. Activity was concentrated in counties with major universities or large increases in the population of 0-17 age group. The ten counties showing the most construction saw their number of 0-17 year olds rise by 71,215 from 1977 to 1993. The other 26 counties, however, had a net loss of 5,397 people in that age group.

School building construction fell sharply in Oregon during the early 1980's as the number of 0-17 year olds in the state declined. Construction bottomed out at 157,800 square feet in 1993 (see Figure Chapter Two -10). In the 1980's, Oregon's population of 0-17 year olds fell 21,564. In the first two years of the 1990's, it has recovered all of that loss. The school aged population is now rising sharply and school building construction has rebounded.

A regression of school building construction with population as an independent variable produces an R^2 of 0.75. When run against just the 0-17 age group, the R^2 rises to 0.80 with a significant T-statistic of 11.7. Construction is also correlated with changes in the 0-17 population. The R^2 in this case is 0.61 with a T-statistic of 7.3. Lower, yet statistically significant, correlation are achieved when the number of college students and population density are used as independent variable.

Several different regression equations were tested in the model. While each equation had a high R^2, the C_0 coefficient caused problems for some small counties. A simpler approach was used. It is based on the potential school population. This is the sum of 0-17 year olds and the number of college students.

Construction was divided up into two parts. The first was replacement building construction which is done because new buildings are needed to replace older ones. The amount of replacement construction is a function of the useful age of school buildings and the size of the school aged population. DOGAMI assumed that 10% of the construction from 1978 to 1993 was done for replacement purposes. That equals 1,531,600 square feet or about 0.112 square feet a year for every potential school age person.

The second type of construction occurs because there is a need for new school space to accommodate a rising population. This was assumed to be 90% of the 1978 to 1993 total or 13,784,800 square feet. Dividing this by the net increase in the potential school age population gives us 151.2 square feet per person. This compares favorably to recent school construction projects in Oregon which have averaged about 200 square feet per student. The figure used in the model is lower because FW Dodge captures about 90% of the total construction and we include the entire population of 0-17 year olds. The replacement and new space factors are used in the model and appears in equation (23)below.

Equation (24) calculates the amount of aggregate used per 1,000 square feet of building construction. This equation adjusts the aggregate usage rate so that it reflects the likely amounts of one-story and multi-story school construction. One-story schools require more aggregate per square foot than multi-story schools. It is assumed that 70% of schools in counties with 12 households per square mile will be one-story. A household density of 12 is about equal to the current state average. This percentage gradually rises to 100% as the density falls toward zero. For higher density counties, the percentage of one-story schools falls to 20% as the density approaches 100 households per square mile. This relationship is shown in Figure Chapter Two -11.

$$(23)\ SCHOC_{C,T} = (10/9) * \{ 0.15122 * [(POP17_{C,T} - POP17_{C,T-1}) + CSPOP_C/HHOR91 * (HHOR_T - HHOR_{T-1})] + 0.000112063 * (POP17_{C,T-1} + CSPOP_C/HHOR91 * HHOR_{T-1})$$

with $SCHOC_{C,T}$ having a minimum value of zero.

(24) $AFSCHO_{C,T}$ = { if [$HHDEN_{C,T}$ < 12 then $AFSCHOL_C$ - [$AFSCHOL_C$ - (0.3 * $AFSCHOHC_C$ + 0.7 * $AFSCHOL_C$) * $HHDEN_{C,T}$ / 12] else if [$HHDEN_{C,T}$ < 100 then (0.3 * $AFSCHOH_C$ + 0.7 * $AFSCHOL_C$) - ((0.3 * $AFSCHOH_C$ + 0.7 * $AFSCHOL_C$) - (0.8 * $AFSCHOH_C$ + 0.2 * $AFSCHOL_C$)) / ($HHDEN_{C,T}$ -12) / 88 else (0.8 * $AFSCHOH_C$ + 0.2 * $AFSCHOL_C$) - ((0.3 * $AFSCHOH_C$ + 0.7 * $AFSCHOL_C$) - (0.8 * $AFSCHOH_C$ + 0.2 * $AFSCHOL_C$)) * ($HHDEN_{C,T}$ - 100) / 1900]] - (if $HHDEN_{C,T}$ < 100 then 0 else ($HHDEN_{C,T}$ -100) / 1900}

(22) $ASCHO_{C,T}$ = ($AFSCHO_{C,T}$ + CPFSCHO) * $SCHOC_{C,T}$ * $TECH_T$

Where:

$SCHOC_{C,T}$ is school building construction in thousands of square feet for a county in a specific future year.

$POP17_{C,T}$ is the population of 0-17 year olds in a county during the specified year.

$CSPOP_C$ equals the number of students attending college in the county during 1991.

HHOR91 is the number of households in Oregon in 1991.

$HHOR_T$ is the number of households in Oregon for the year specified.

$AFSCHO_{C,T}$ equals the amount of aggregate used in direct forms for every 1,000 square feet of school building space added.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$AFSCHOL_C$ is the amount of aggregate used in direct forms for building 1,000 square feet of a one story school building. It equals 310 tons in western Oregon counties and 270 tons in other, drier counties.

$AFSCHOH_C$ is the amount of aggregate used in direct forms for building 1,000 square feet of a multi-story school building. It equals 213.1 tons in eastern and central Oregon. It is 233.1 tons in western Oregon where more aggregate is needed because of the greater rainfall.

$ASCHO_{C,T}$ is the amount of aggregate used in school building construction in a county in a specific year.

CPFSCHO equals the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon per thousand square feet of school building construction. It equals about 229 tons.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -9

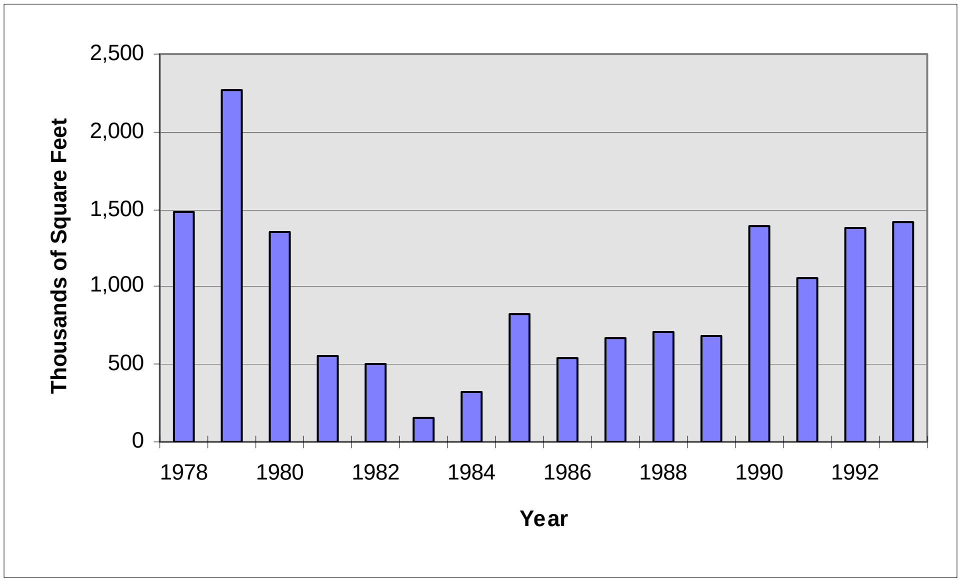
School Building Construction by County
Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./Year*
Baker	4.3
Benton	34.6
Clackamas	127.2
Clatsop	20.7
Columbia	16.8
Coos	8.3
Crook	0.3
Curry	4.4
Deschutes	66.5
Douglas	11.7
Gilliam	0.0
Grant	1.2
Harney	0.0
Hood River	0.0
Jackson	32.1
Jefferson	0.1
Josephine	9.2
Klamath	8.2
Lake	3.6
Lane	54.7
Lincoln	7.4
Linn	12.8
Malheur	2.6
Marion	109.4
Morrow	6.5
Multnomah	143.9
Polk	20.5
Sherman	2.6
Tillamook	8.7
Umatilla	23.7
Union	5.5
Wallowa	0.5
Wasco	3.8
Washington	167.5
Wheeler	0.8
Yamhill	37.0
Total	957.3

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -10

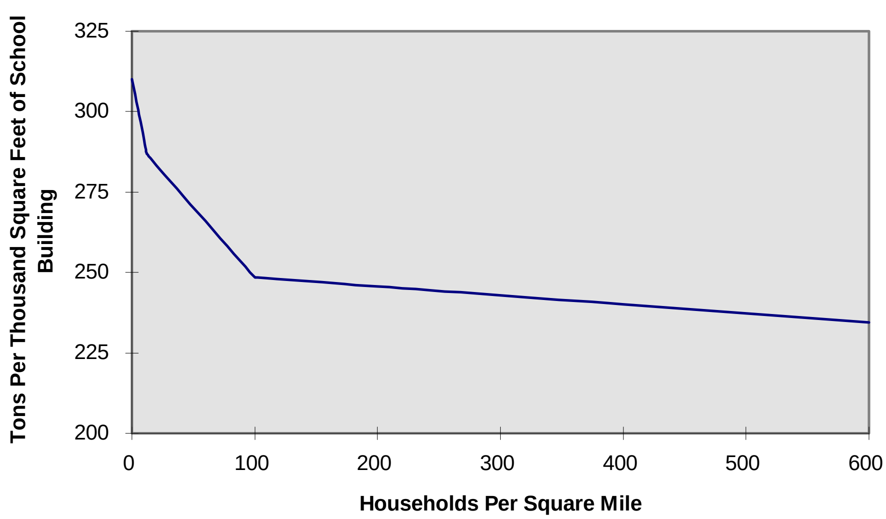
Oregon School Building Construction
Thousands of Square Feet



Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -11

Aggregate Usage Rates Versus Household Densities for Western Oregon School Construction



Source: DOGAMI county aggregate models.

Municipal Buildings

The municipal buildings series contains police stations, fire houses, post offices, city halls, courthouses, armories, and other related buildings. Construction is measured in thousands of square feet. Municipal buildings contribute 0.2% to the total amount of aggregate consumption forecast for Oregon.

The municipal building series is small. On Table Chapter Two -10, the average annual construction for 1978 to 1993 in Oregon's 36 counties is shown. During that 16 year period a total of 2,479,700 square feet of municipal building construction was contracted for according to FW Dodge. Multnomah County alone accounted for 42% of the total. Washington and Clackamas, the two other counties in the Portland area, made up another 18%. Several other large or growing counties reported significant construction. None was recorded, however, in nine counties.

Municipal building construction consists mostly of many small projects with an occasional large office building. As such, the series does not follow any obvious pattern. This can be seen in Figure Chapter Two -12.

With an unusually large share of the construction taking place in the Portland metropolitan area, it is no surprise that the municipal building series is highly correlated with household density and real personal income. The R^2 of the series in a regression with the number of households per square mile is 0.95 with a T-statistic of 25.3. When regressed using real personal income as the independent variable, the R^2 is 0.85. A lower R^2 of 0.51 is achieved when using the change in personal income. The correlation with changes in population is only slightly significant. In this case the R^2 is just 0.29.

The equation used in the model incorporates the change in personal income and household density. Its R^2 is 0.96. Since municipal construction projects are often paid for with local taxes, construction is related to the incomes. This is captured in the first independent variable. Its T-statistic, at +2.0, is just significant. Density reflects the size and degree of urbanization. These are factors which correlate well with the amounts of past municipal building construction. The T-statistic for this variable is a highly significant +18.1.

The municipal building construction equations are:

(23) $MUNIC_{C,T} = (10/9) * \{ 0.375449 + .000026645 * (PI_{C,T} - PI_{C,T-1}) + 0.108368 * HHDEN_{C,T} + CAFMUNI_C \}$

with $MUNIC_{C,T}$ having a minimum value of zero.

(24) $TAFMUNI_{C,T} = AFMUNI_C + CPFMUNI - ($ if $HHDEN_{C,T} < 100$ then 0 else $20 * (HHDEN_{C,T} - 100) / 1900)$

(25) $AMUNI_{C,T} = MUNIC_{C,T} * TAFMUNI_{C,T} * TECH_T$

Where:

$MUNIC_{C,T}$ equals the thousands of square feet of municipal building construction in a given county for a given year.

$PI_{C,T}$ is the total real personal income in a county for a specified year. It is in terms of thousands of 1987 dollars.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$CAFMUNI_C$ is the county adjustment factor for municipal building construction. It equals the difference between the historical actual and fitted results for this equation.

$TAFMUNI_{C,T}$ is the amount of aggregate of all types used for every 1,000 square feet of municipal building construction in a county for a certain year.

$AFMUNI_C$ is the amount of aggregate used for every 1,000 square feet of municipal building construction in direct forms, as ready-mix concrete, and as asphalt. In eastern Oregon it equals 320 tons. In western Oregon, because of the wetter climate, this factor equals 360 tons.

CPFMUNI equals about 16 tons per thousand square feet of municipal building construction. It is the amount of aggregate contained in finished concrete and masonry products brought in during construction.

$AMUNI_{C,T}$ is the total amount of aggregate consumed in a county for a given year for the construction of municipal buildings.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -10

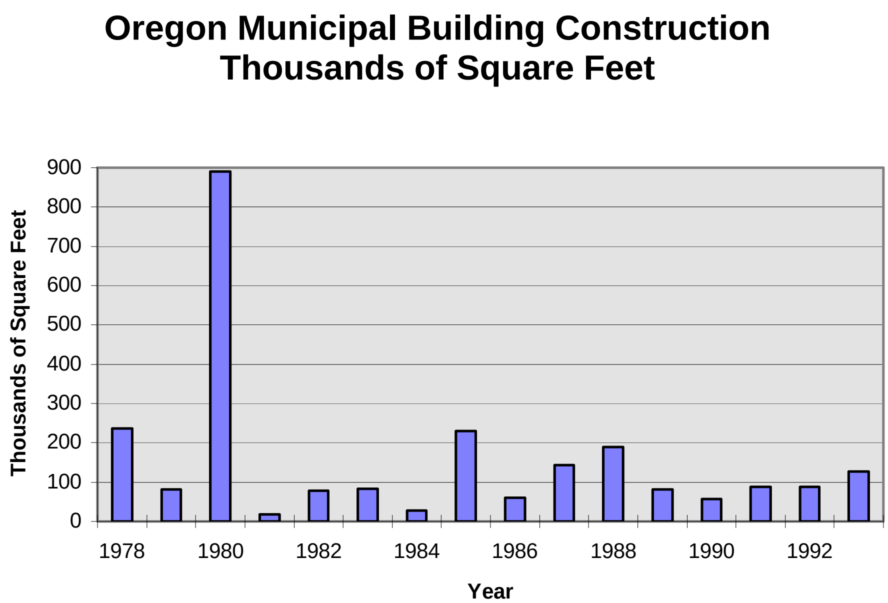
Municipal Building Construction by County
Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./Year*
Baker	0.7
Benton	0.3
Clackamas	14.8
Clatsop	2.9
Columbia	1.9
Coos	2.7
Crook	0.1
Curry	0.0
Deschutes	7.1
Douglas	1.2
Gilliam	0.0
Grant	0.0
Harney	0.0
Hood River	3.8
Jackson	7.0
Jefferson	0.7
Josephine	0.3
Klamath	0.4
Lake	0.5
Lane	7.7
Lincoln	3.8
Linn	1.9
Malheur	0.0
Marion	9.7
Morrow	0.7
Multnomah	64.8
Polk	0.4
Sherman	0.0
Tillamook	2.5
Umatilla	3.3
Union	0.0
Wallowa	0.1
Wasco	0.0
Washington	12.7
Wheeler	0.0

Yamhill	3.2
Total	155.0

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -12



Source: FW Dodge data modified by DOGAMI.

Public Assembly Buildings

Public assembly buildings are places, other than schools, where people meet for recreation, social, and education pursuits. Included are auditoriums, theaters, club houses, lodges, casinos, exhibition halls, libraries, bowling alleys, sports areas, convention halls, religious buildings, funeral homes, museums, and recreation centers. Construction of these buildings is measured in thousands of square feet of floor space. Aggregate consumption covers the buildings themselves as well as site preparation, staging areas, sidewalks, parking lots, outdoor gathering areas, other features. In total, public assembly building construction is expected to equal 1.1% of total aggregate consumption in Oregon from 2001 to 2050.

According to the historical data provided by FW Dodge, public assembly building construction occurred in all but two Oregon counties from 1978 to 1993 (see Table Chapter Two -11). Construction was distributed fairly evenly according to county populations. About 88% of the building activity took place in western Oregon where 87% of the state's population resides.

Statewide totals from 1978 through 1993 are shown in Figure Chapter Two -13. The series is composed of many small projects for buildings such as churches, athletic clubs, and libraries. At times large projects, such as the Oregon Convention Center in Multnomah County, cause an upward spike in the data.

Public assembly building activity declined sharply from the construction boom period of the late 1970's. Construction of building space got ahead of population growth. After an unexpected period of population losses and weak economic conditions, construction hit a low of about 500,000 square feet in 1984. It slowly recovered since then as excess building capacity was absorbed and the state's population grew once again.

Public assembly building construction is highly correlated to county population and income. The R^2 of construction using population as the independent variable is 0.96 with a highly significant T-statistic of 29.7. When total households are used, the T-statistic falls slightly to 28.4. Population is a better predictor of how much assembly space is constructed. If change in population is used as an independent variable, the R^2 is 0.53 with a T-statistic of 6.3. A better result is achieved with real personal income. The R^2 in that case is 0.97.

Equation (26), which is shown below, is used in the model. It uses population and the percent of population living in urban areas as independent variables. The R^2 of the regression equation is 0.96 with T-statistics of +20.8 and -1.5, respectively. Construction is highly correlated with population size. Based on the equation, about 490 square feet are built each year for every 1,000 people. There is a slight negative effect, however, in urbanized areas where public assembly buildings are more heavily used.

Other equations were tried for this series. Personal income works well as an explanatory variable, although it tends to under estimate the amount of construction in rural counties. Population growth helps explain the impact of new residents, but for counties with declining or static populations the variable produces poor results. Population growth is also highly correlated with population levels and this creates a multicollinearity problem when both are used in the same equation.

The public assembly building construction equations are:

(26) $PAC_{C,T} = (10/9) * \{ 16 + 0.00049 * POP_{C,T} - 32.4 * URB_{C,T} + CAFPA_C \}$

with $PAC_{C,T}$ having a minimum value of zero.

(27) $TAFPA_{C,T} = AFPA_C + CPFPA - (\text{if } HHDEN_{C,T} < 100 \text{ then } 0 \text{ else } 20 * (HHDEN_{C,T} - 100) / 1900)$

(28) $APA_{C,T} = PAC_{C,T} * TAFPA_{C,T} * TECH_T$

Where:

$PAC_{C,T}$ equals the thousands of square feet of public assembly building floor space constructed in a given county for a given year.

$POP_{C,T}$ is the total population of a county for a specified year.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

$CAFPA_C$ is the county adjustment factor for public assembly building construction. It equals the difference between the historical actual and fitted results for this equation.

$TAFPA_{C,T}$ is the amount of aggregate of all types used for every 1,000 square feet of public assembly building construction in a county for a certain year.

$AFPA_C$ is the amount of aggregate used for every 1,000 square feet of public assembly building construction in direct forms. In eastern Oregon, where dryer weather means less aggregate is needed, it equals 270 tons. In western Oregon it is 310 tons.

CPFPA equals about 16 tons per thousand square feet of public assembly building construction. It is the amount of aggregate contained in finished concrete and masonry products brought in during construction.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$APA_{C,T}$ is the total amount of aggregate consumed in a county for a given year for the construction of public assembly buildings.

$TECH_T$ is the statewide technology factor for the forecast year.

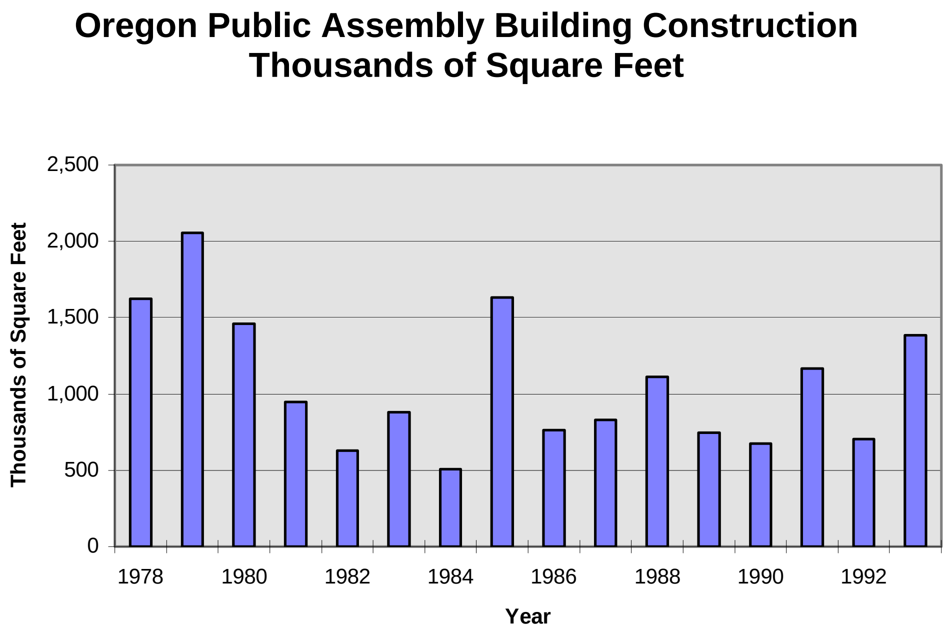
Table Chapter Two -11

Public Assembly Building Construction by County
Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./Year*
Baker	7.0
Benton	31.0
Clackamas	148.0
Clatsop	9.6
Columbia	7.0
Coos	11.1
Crook	1.7
Curry	5.0
Deschutes	38.2
Douglas	24.1
Gilliam	0.0
Grant	1.8
Harney	2.7
Hood River	4.7
Jackson	32.8
Jefferson	2.9
Josephine	16.0
Klamath	9.1
Lake	2.0
Lane	124.7
Lincoln	16.3
Linn	22.1
Malheur	8.9
Marion	90.1
Morrow	2.1
Multnomah	269.4
Polk	8.8
Sherman	1.5
Tillamook	3.1
Umatilla	9.7
Union	5.8
Wallowa	0.9
Wasco	11.1
Washington	104.8
Wheeler	0.0
Yamhill	36.0
Total	1,069.6

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -13



Source: FW Dodge.

Airport Buildings

Airport building construction is measured in thousands of square feet of floor space. The types of buildings in this series are terminals, aircraft maintenance facilities, and hanger. Large quantities of aggregate are needed because these building often have features that help provide better access for people, cars, buses, and trucks. Some of these include roads, curbs, walkways, outdoor lighting, and loading areas. The total amount of airport building construction, however, is small. Therefore, in the forecast for Oregon, airport buildings make up just 0.2% of total aggregate consumption.

From 1978 to 1993, a total of 2,490,100 square feet of airport buildings were put-up in Oregon according to FW Dodge. That is roughly the equivalent of one medium sized high school a year. There was no construction in 16 counties (see Table Chapter Two -12). Multnomah County alone, which has Portland International Airport, accounted for 74% of all the airport building construction in the state. The next three highest had 16%. They are Deschutes, Land, and Jackson Counties. All three have commercial airports.

Over 92% of the airport building construction took place in the eight Oregon counties that have commercial airports. The remaining 8% was spread over 12 other counties.

In most years, fewer than 100,000 square feet of airport buildings are constructed. Periodically, large projects go up. These appear as large spikes on Figure Chapter Two -14. It shows the amount of construction each year in Oregon from 1978 through 1993.

Airport building construction is moderately correlated with county population. A regression using population as an independent variable produces an R^2 of 0.54. Better results are achieved when the number of households is used. In this case, the R^2 is 0.60. Changes in population and numbers of households both generate a much lower R^2, although they are still statistically significant. The best R^2 comes from using population density as an independent variable. It works out to 0.89.

Using regression analysis does create statistically significant results, but the equations perform poorly when used in forecasts. This is because Multnomah County has an overwhelming impact on regression results. This causes large over estimations when they are used to forecast construction in urban counties with no commercial airports, such as Clackamas and Washington. If a dummy variable for commercial airports is employed, the regression statistics improve. The forecast results are still biased because the commercial airport in Multnomah County is substantially different than others in the state.

For the model, a simple approach was used. A ratio of airport building construction to the number of households was calculated for the 1978 to 1993 period. For each county, this ratio equals the number of square feet built annually for each household. The ratio is then multiplied by the forecast for the number of households. This provides a forecast for airport building construction.

The airport building construction equations are:

(29) $AIRBC_{C,T} = (10/9) * (AIRBR_C * HH_{C,T})$

with $AIRBC_{C,T}$ having a minimum value of zero.

(30) $AAIRB_{C,T} = (AFAIRB_C + CPFAIRB) * AIRBC_{C,T} * TECH_T$

Where:

$AIRBC_{C,T}$ equals the thousands of square feet of airport building floor space constructed in a given county for a given year.

$AIRBR_C$ is the historical ratio in a county for the square feet of airport buildings constructed each year from 1978 to 1993 divided by the average number of households.

$HH_{C,T}$ is the number of households living in a county in a given year.

$AAIRB_{C,T}$ equals the number of tons of aggregate used in airport building construction in a county for a specified year.

$AFAIRB_C$ is the amount of aggregate used for every 1,000 square feet of airport building construction in direct forms. It equals 408.6 tons in western Oregon and 368.6 tons in eastern Oregon.

CPFAIRB is about 30 tons per thousand square feet of airport building construction. It is the amount of aggregate contained in finished concrete and masonry products brought in during construction.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -12

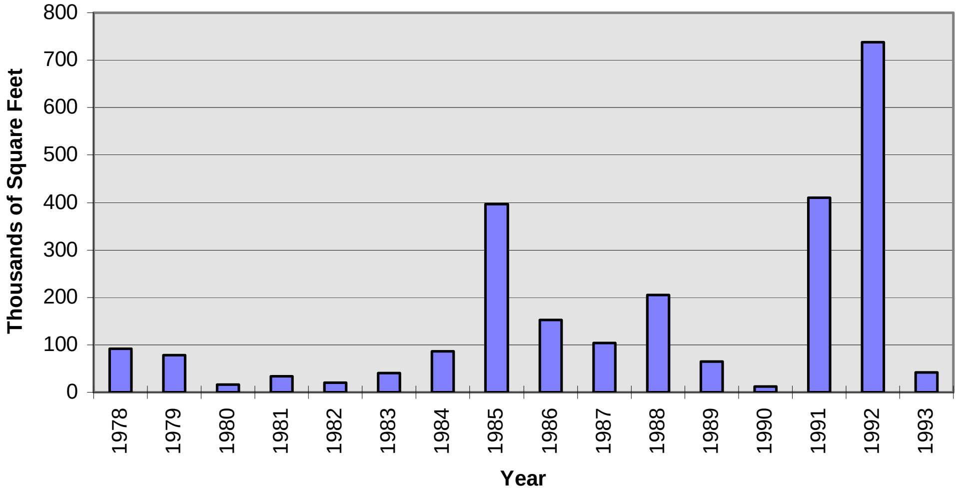
Airport Building Construction by County
Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./Year*
Baker	0.0
Benton	2.3
Clackamas	0.2
Clatsop	0.9
Columbia	0.4
Coos	1.1
Crook	0.2
Curry	0.0
Deschutes	12.7
Douglas	1.4
Gilliam	0.0
Grant	0.0
Harney	0.0
Hood River	0.7
Jackson	5.4
Jefferson	1.1
Josephine	0.0
Klamath	0.2
Lake	0.0
Lane	7.2
Lincoln	0.0
Linn	0.3
Malheur	0.0
Marion	2.3
Morrow	0.0
Multnomah	115.2
Polk	0.0
Sherman	0.0
Tillamook	0.2
Umatilla	0.3
Union	0.0
Wallowa	0.0
Wasco	0.0
Washington	2.6
Wheeler	0.0
Yamhill	0.9
Total	155.6

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -14

Oregon Airport Building Construction
Thousands of Square Feet



Source: FW Dodge.

Sewer and Water

The sewer and water construction series accounts for 9.7% of the aggregate consumption in the forecast. It includes work on sanitary sewers, sewage plants, sewage lines, water lines, water tanks, water treatment plants, flood control structures, storm sewers, and waste water treatment facilities. This series does not usually include sewer and water construction spending for specific buildings or houses. Construction is measured for this series in thousands of 1987 dollars.

Table Chapter Two -13 shows the annual average spending on sewer and water construction by county for the period from 1978 to 1993. During that time a total of $1,901,685,000 (1987 dollars) were spent according to FW Dodge. Construction took place in every county. The least amount was reported by Gilliam County. They spent an average of $119,000 a year. The most was spent in Multnomah County.

Annual spending on sewer and water projects in Oregon varies, in most years, between $75 and $125 million 1987 dollars. Deviations from that occur in years of unusually strong or weak growth. Data for Oregon are shown in Figure Chapter Two -15.

Sewer and water projects are generally done for towns, cities, and suburbs. The extent of features, such a water lines, are most dependent on the number of households and not on the size of the population. This is evident from regression equations. The R^2 of sewer and water construction using population change as the independent variable is 0.54. The R^2 using the change in households, at 0.67, is appreciably larger. Much of the construction spending on sewer and water takes place, not because of growth, but to satisfy the changing needs of exiting residents and businesses. The R^2 using total households as the independent variable is 0.94 with a highly significant T-statistic of 23.2. Sewer and water projects are usually done in areas where businesses or homes are clustered. By taking out households that live in rural areas outside of towns, the R^2 goes up to 0.95 and the T-statistic rises to 25.8.

The equation used in the model uses both the level and change in the number of households as explanatory variables. Households located in census blocks where there are fewer than one household per ten acres are excluded. The equation has an R^2 of 0.96. No adjustments for differences between fitted and actual historical values are used. The equation, which is number 31 below, does set a minimum value of 100. This is above the lowest historical average for any county in the state. The minimum prevents a negative value forecast in counties whose household forecast shows a decline.

The sewer and water construction equations are:

(31) $SWC_{C,T} = (10/9) * (152.49 + 0.111218 * HH_{C,T} * URB_{C,T} + 0.952468 * (HH_{C,T} - HH_{C,T-1}) * URB_{C,T})$

with $SWC_{C,T}$ having a minimum value of 100.

(32) $ASW_{C,T} = (AFSW_C + CPFSW) * SWC_{C,T} * TECH_T$

Where:

$SWC_{C,T}$ equals the thousands of 1987 dollars spent on sewer and water construction projects. square feet of airport building floor space constructed in a given county for a given year.

$HH_{C,T}$ is the number of households living in a county in a given year.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

$ASW_{C,T}$ equals the number of tons of aggregate used in sewer and water construction in a county for a specified year.

$AFSW_C$ is the amount of aggregate directly used for every one thousand 1987 dollars of construction spending for sewer and water projects. It equals about 24 tons in western Oregon and 21 tons in the rest of the state.

CPFSW is about 1.9 tons per thousand 1987 dollars of sewer and water construction project spending. It is the amount of aggregate contained in finished products brought in during construction.

$TECH_T$ is the statewide technology factor for the forecast year.

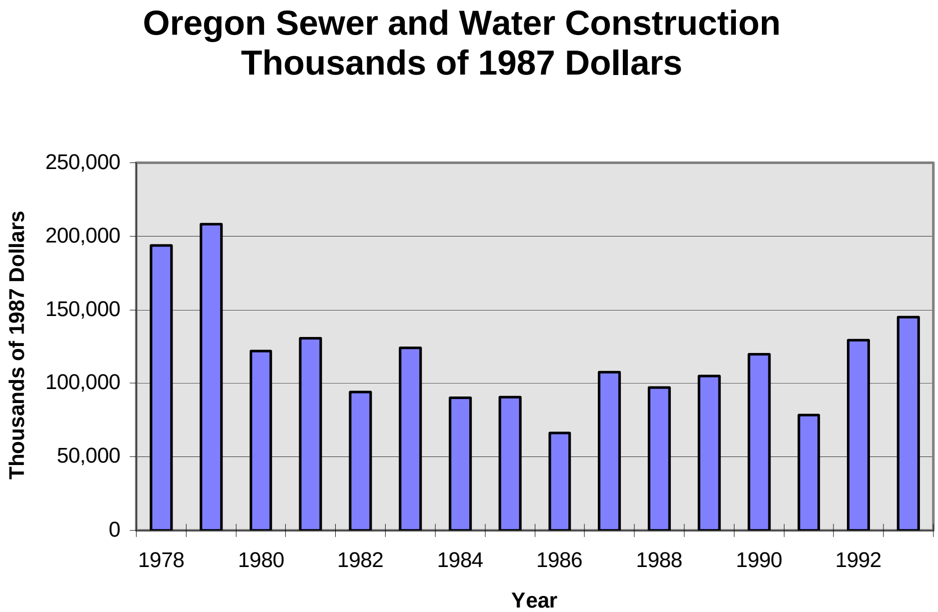
Table Chapter Two -13

Sewer and Water Construction Spending by County
Annual Averages 1978 - 1994

County	*Thousands of 1987 $*
Baker	698
Benton	2,272
Clackamas	8,755
Clatsop	1,352
Columbia	1,181
Coos	3,266
Crook	241
Curry	986
Deschutes	4,305
Douglas	4,481
Gilliam	119
Grant	828
Harney	154
Hood River	728
Jackson	2,777
Jefferson	875
Josephine	1,144
Klamath	1,519
Lake	155
Lane	10,223
Lincoln	3,548
Linn	3,539
Malheur	911
Marion	6,153
Morrow	890
Multnomah	29,599
Polk	1,111
Sherman	253
Tillamook	1,668
Umatilla	3,036
Union	637
Wallowa	486
Wasco	610
Washington	16,616
Wheeler	557
Yamhill	3,180
Total	118,855

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -15



Source: FW Dodge.

Warehouses

Warehouses include all manufacturer and non-manufacturer owned buildings. This series is divided up between refrigerated and non-refrigerated warehouses. This distinction is made because refrigerated warehouses require over 20% more aggregate for their construction than non-refrigerated warehouses. In total, warehouses account for 3.1% of forecast aggregate consumption. Of this, 2.9% will be used for non-refrigerated buildings.

FW Dodge counted 39,348,000 square feet of warehouse building construction from 1978 through 1993 in Oregon. Construction was recorded in all but one county.

Most of the non-refrigerated warehouses were built in Multnomah, Clackamas, and Washington Counties. Seventy-four percent of the non-refrigerated warehouse space was built in those three counties. They encompass most of the Portland metropolitan area.

Refrigerated warehouses made up 3.9% of the total (see Table Chapter Two -14). Many of these refrigerated warehouses were built for the food processing industry. Construction, therefore, tended to be in agricultural counties. Marion County, which grows much of the state's vegetable crops, led in the construction of refrigerated warehouses.

Warehouse construction fell dramatically after 1980 and has yet to completely recover. Data for Oregon are shown on Figure Chapter Two -16. Some of the losses since 1980 are due to cutbacks in the forest products industry. There has also been a significant over supply of warehouse space which has taken a long time to be absorbed.

Most warehouse space is used by manufacturers and retailers. Over the 1978 to 1993 period, an average of 608 square feet of warehouse space has been built for every 1,000 square feet of manufacturing and retail space constructed. Most years have averaged between 400 and 800 square feet. In counties like Washington, where much of the manufacturing base is electronics, the average has been 513 square feet. In Clackamas County, which has more heavy industry, the average is 745 square feet. Multnomah County, however, stands out as an unusual exception in Oregon. With a huge international port facility, extensive rail yards, and two major interstate highways, Multnomah County requires large amounts of warehouse space. From 1978 to 1993, it added 1,383 square feet of warehouses for every thousand square feet of retail and manufacturing space.

Non-refrigerated warehouse construction is highly correlated with population and population density. It is also closely tied to the building of retail and manufacturing space. Counties which are traversed by Interstate 5 and 84 tend to have larger amounts of warehouse space construction than those that have either limited or no direct access. The best performing equation (contains two independent variables and has an R^2 of 0.98.

The first independent variable is the construction of retail and manufacturing space. It is in thousands of square feet and is adjusted downwards by nine-tenths so that it conforms to the historical FW Dodge data series used in the regression. The T-statistic for this independent variable is 18.2, indicating that it is highly significant. The second independent variable is population density multiplied by a dummy variable for major interstate highway access. For counties that have at least ten miles of direct access to Oregon's two major interstate highways (I-5 and I-84), the dummy variable equals one. For other counties, the variable equals zero. The T-statistic for the second independent variable is 17.6.

For refrigerated warehouses, numerous equations were tested, but they were all unsatisfactory. Refrigerated warehouse construction amounts to little more than 90,000 square feet a year and the location of this activity is dictated mostly by local characteristics that cannot be easily modeled. Because of these reasons a simple approach was used. The historical ratio of refrigerated to non-refrigerated warehouse construction was calculated for each county. The ratios are shown on Table Chapter Two -14. Counties were then ranked by their ratios and grouped into six units of six. The overall ratio for each group was calculated. These group ratios are used to forecast refrigerated warehouse construction. For the two lowest groups, for which no refrigerated warehouse construction took place from 1978 to 1993, a minimum ratio of 0.75% is used.

The warehouse construction equations are:

(31) $WHC_{C,T} = (10/9) * \{ CAFWH_C - 14.5145 + 0.502693 * (9/10) * (RETC_{C,T} + MANFC_{C,T}) + 0.441197 * (DI584_C * POPDEN_{C,T})\}$

with $WHC_{C,T}$ having a minimum value of zero.

(32) $RWC_{C,T} = RWPCT_C * WHC_{CT}$

(33) $AWH_{C,T} = (AFWH_C + CPFWH) * WHC_{C,T} * TECH_T$

(34) $ARW_{C,T} = (AFRW_C + CPFRW) * RWC_{C,T} * TECH_T$

Where:

$WHC_{C,T}$ is the amount of non-refrigerated warehouse space built in a county for a specific year. It is in terms of thousands of square feet.

$CAFWH_C$ is the county adjustment factor for non-refrigerated warehouse construction. It equals the difference between the historical actual and fitted results for this equation.

$RETC_{C,T}$ is retail building construction in thousands of square feet for a county in a specific future year.

$MANFC_{C,T}$ is manufacturing plant and lab building construction in thousands of square feet for a county in a specific future year.

$DI584_C$ is a dummy variable that equals one for any county that has at least ten miles of Interstate 5 or 84 crossing it. For other counties, the variable equals zero.

$POPDEN_{C,T}$ is the population density for a county in a given year. It is in terms of people per square mile of land.

$RWC_{C,T}$ is the construction of refrigerated warehouse space in a county for a given year. It is measured in thousands of square feet of floor space.

$RWPCT_C$ is the ratio of refrigerated to non-refrigerated warehouse space for the group of six counties that this specific county belongs to. The ratio is the actual value for the six counties for the 1978 to 1993 period. Counties were grouped together in order of their individual historical ratios.

$AWH_{C,T}$ equals the tons of aggregate used to build non-refrigerated warehouses in a county for a given year.

$AFWH_C$ is the aggregate usage rate for non-refrigerated warehouses. It does not include aggregate contained in finished concrete products. The usage rate for eastern and central Oregon counties is 310 tons per thousand square feet of construction. For western Oregon, the rate is 350 tons.

CPFWH is the usage rate of concrete products for non-refrigerated warehouse construction. It equals approximately 23 tons per thousand square feet.

$TECH_T$ is the statewide technology factor for the forecast year.

$ARW_{C,T}$ equals the tons of aggregate used to build refrigerated warehouses in a county for a given year.

$AFRW_C$ is the usage rate of aggregate directly used or used in mixes during the construction of refrigerated warehouses. The usage rate for eastern and central Oregon counties is 380 tons per thousand square feet of construction. For western Oregon, the rate is 420 tons.

CPFRW is the usage rate of concrete products for refrigerated warehouse construction. It equals approximately 26 tons per thousand square feet.

Table Chapter Two -14

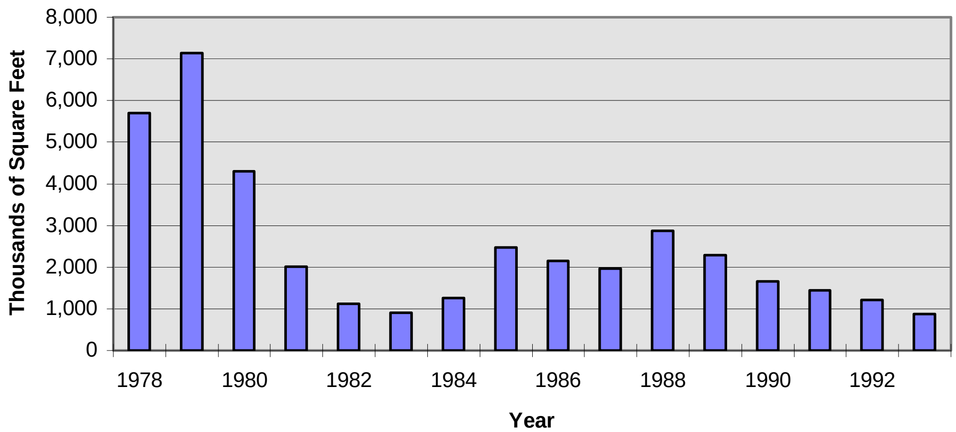
Warehouse Construction by County
Annual Averages 1978 - 1994
Thousands of Square Feet

County	Non-Refrigerated Warehouses	Refrigerated Warehouses	Ratio of Refrigerated to Non-Refrigerated
Baker	1.1	0.7	57.4%
Benton	10.1	0.0	0.0%
Clackamas	415.6	3.6	0.9%
Clatsop	12.9	0.0	0.0%
Columbia	10.4	0.0	0.0%
Coos	3.2	0.0	0.0%
Crook	24.3	0.3	1.2%
Curry	1.6	0.0	0.0%
Deschutes	23.8	2.8	11.8%
Douglas	9.9	1.2	12.1%
Gilliam	0.4	0.0	0.0%
Grant	0.7	0.3	47.4%
Harney	1.6	0.4	22.4%
Hood River	1.0	0.3	28.5%
Jackson	62.6	12.5	20.0%
Jefferson	7.1	0.1	1.1%
Josephine	2.3	0.3	10.9%
Klamath	6.8	0.9	13.7%
Lake	0.6	0.7	116.9%
Lane	156.1	9.9	6.3%
Lincoln	9.6	1.3	13.0%
Linn	30.2	0.0	0.0%
Malheur	11.3	0.0	0.0%
Marion	166.6	24.4	14.6%
Morrow	2.8	0.0	0.0%
Multnomah	903.9	8.8	1.0%
Polk	16.3	0.0	0.0%
Sherman	15.6	0.0	0.0%
Tillamook	1.4	0.3	19.4%
Umatilla	13.1	4.5	34.8%
Union	2.1	0.0	0.0%
Wallowa	1.2	0.0	0.0%
Wasco	1.5	0.0	0.0%
Washington	426.8	18.9	4.4%
Wheeler	0.0	0.0	0.0%
Yamhill	12.7	0.1	0.5%
Total	2,367.3	92.0	3.9%

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -16

Oregon Warehouse Construction
Thousands of Square Feet



Source: FW Dodge.

Miscellaneous Non-Residential Buildings

The miscellaneous non-residential building series includes such things as fish hatcheries and veterinary offices. But the series is dominated by transportation services such as bus terminals, service buildings for trucks and railroads, and freight terminals for marine, air, and rail transportation. In the forecast, all of these structures account for 0.5% of the projected aggregate consumption in Oregon.

As can be seen in Table Chapter Two -15, all but one county reported some construction of miscellaneous non-residential buildings from 1978 to 1993. Total construction during the 16 year period was 6,511,000 square feet. Just under half of the total square footage was built in the Portland area counties of Multnomah, Clackamas, and Washington. A strong link to how much construction took place is interstate highway access. Interstate 5 and 84 are the two interstate highways which cross Oregon. Just 17 of Oregon's 36 counties have at least 10 miles of these interstate crossing them. Those 17 counties accounted for 73% of the miscellaneous non-residential building construction on Table Chapter Two -15.

Construction of miscellaneous non-residential buildings is dominated by freight terminals and transportation service buildings. Between 1978 and 1981, there was great deal of construction of these structures throughout the state. Since then, there have been relatively few large projects (see Figure Chapter Two -17).

Miscellaneous building construction is highly correlated with county populations. A regression using population as an independent variable has an R^2 of 0.93. Using population in a forecast equation, however, created problems because it drowned out the influence of other variables while not fully capturing the effects of growth. Construction is only modestly correlated with changes in population. That variable produces an R^2 of 0.30. Change in real personal income provides a much higher R^2 of 0.61. This is substantially more significant and has a T-statistic of 7.4. Household density is also significant. If multiplied by a dummy variable for counties with direct interstate highway access, the R^2 is 0.80. This independent variable equals zero for counties with less than ten miles of I-5 or I-84 interstate highway mileage. For others, it equals the household density of the county.

The model uses an equation (35) that contains two independent variables. They are the change in real personal income and household density multiplied by a dummy variable for direct interstate highway access. The first variable captures growth effects. It has a T-statistic of 7.9. The second considers the level of density and highway access. Both are important for the citing of freight terminals. The variable has a T-statistic of 12.1. The R^2 for this equation is 0.93.

The miscellaneous non-residential building construction equations are:

(35) $MNRBC_{C,T} = (10/9) * \{ CAFMNRB_C + 2.23864 + 0.00023449 * (PI_{C,T} - PI_{C,T-1}) + 0.169788 * (DI584_C * HHDEN_{C,T})\}$

with $MNRBC_{C,T}$ having a minimum value of zero.

(36) $TAFMNRB_{C,T} = AFMNRB_C + CPFMNRB$ - if ($HHDEN_{CT}$<100 then 0 else 20 * ($HHDEN_{CT}$-100)/1900)

(37) $AMNRB_{C,T} = TAFMNRB_{C,T} * MNRBC_{C,T} * TECH_T$

Where:

$MNRBC_{C,T}$ is the amount of miscellaneous non-residential building space constructed in a county for a specific year. It is in terms of thousands of square feet.

$CAFMNRB_C$ is the county adjustment factor for miscellaneous non-residential building construction. It equals the difference between the historical actual and fitted results for this equation.

$PI_{C,T}$ is the total real personal income in a county for a specified year. It is in terms of thousands of 1987 dollars.

$DI584_C$ is a dummy variable that equals one for any county that has at least ten miles of Interstate 5 or 84 crossing it. For other counties, the variable equals zero.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$TAFMNRB_{C,T}$ equals the tons of aggregate used for every 1,000 square feet of miscellaneous non-residential buildings constructed.

$AFMNRB_{C}$ is the aggregate used in forms other than precast concrete and masonry products for every thousand square feet of miscellaneous non-residential buildings constructed. The rate is 350 tons for eastern Oregon and 390 tons fore western Oregon.

CPFMNRB is the usage rate of pre-cast concrete and masonry products for miscellaneous non-residential building construction. It equals approximately 11 tons per thousand square feet.

$AMNRB_{C,T}$ equals the amount of aggregate used in a county for a specific year in the construction of all miscellaneous non-residential buildings.

$TECH_{T}$ is the statewide technology factor for the forecast year.

Table Chapter Two -15

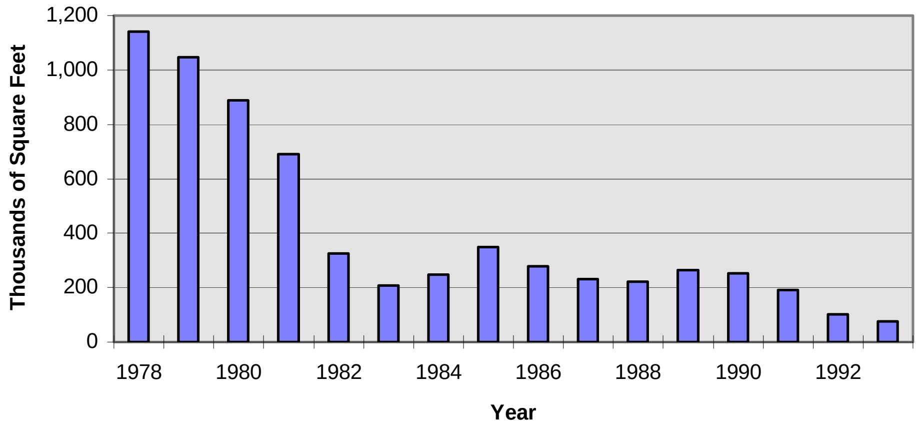
Miscellaneous Non-Residential Building Construction by County Annual Averages 1978 - 1993

County	*Thousands of Sq. Ft./Year*
Baker	0.4
Benton	6.1
Clackamas	28.0
Clatsop	3.6
Columbia	5.6
Coos	2.3
Crook	1.1
Curry	0.5
Deschutes	9.7
Douglas	9.9
Gilliam	1.1
Grant	0.3
Harney	1.9
Hood River	0.7
Jackson	17.0
Jefferson	0.8
Josephine	3.7
Klamath	8.3
Lake	0.8
Lane	46.7
Lincoln	2.2
Linn	3.5
Malheur	0.2
Marion	35.8
Morrow	6.0
Multnomah	127.1
Polk	2.1
Sherman	0.5
Tillamook	1.5
Umatilla	5.3
Union	11.1
Wallowa	3.1
Wasco	1.8
Washington	45.8
Wheeler	0.0
Yamhill	12.7
Total	406.9

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -17

Oregon Miscellaneous Non-Residential Building Construction Thousands of Square Feet



Source: FW Dodge.

Miscellaneous Non-Building Construction

Many types of construction come under the miscellaneous non-building category. Among the most important are communications lines, tunnels, military facilities, waste disposal sites, lighting systems, pools, stadiums, transmission towers, athletic fields, parks, and landfills. Miscellaneous non-building construction uses about 2.2% of all the aggregate in Oregon.

Miscellaneous non-building construction has occurred in all 36 counties in the 1978 to 1993 period. About 42% of the construction spending in this category took place in the Portland metropolitan area. Non-building construction is closely correlated with population growth and household densities.

The model uses equations 38 and 39 to forecast aggregate consumption for miscellaneous non-building construction. Equation 38, which estimates the value of construction spending in each county, has an R^2 of 0.85. The independent variables are household density and change in the total population. The T-statistics for those two variables are 9.8 and 3.3, respectively. The equation is constrained to forecast a value no less than 20. This is done to prevent a negative or extremely low forecast in the event the model is used to forecast a county with a sharply declining population.

The miscellaneous non-building construction equations are:

(38) $MNBC_{C,T} = (10/9) * \{ CAFMNB_C + 300.93 + 14.988\ HHDEN_{C,T} * 0.260695 * (POP_{C,T} - POP_{,T-1}) \}$

with $MNBC_{C,T}$ having a minimum value of 20.

(39) $AMNB_{C,T} = (CPFMNB + AFMNB) * MNBC_{C,T} * TECH_T$

Where:

$MNBC_{C,T}$ is the amount of miscellaneous non- building construction spending occurs in a county for a specific year. It is in terms of thousands of 1987 dollars.

$CAFMNB_C$ is the county adjustment factor for miscellaneous non- building construction. It equals the difference between the historical actual and fitted results for this equation.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$POP_{C,T}$ is the total population of a county for the specified year.

$AMNB_{C,T}$ equals the amount of aggregate used in a county for a specific year in the construction of all miscellaneous non-buildings.

CPFMNB is the amount of aggregate contained in precast concrete and other finished concrete products used in non-building construction. It is set to 0.023 tons per thousand 1987 dollars.

AFMNB is the amount of aggregate used at non-building construction sites for every thousand 1987 dollars spent. It is set to eight tons in eastern Oregon and 10 tons in western Oregon.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -16

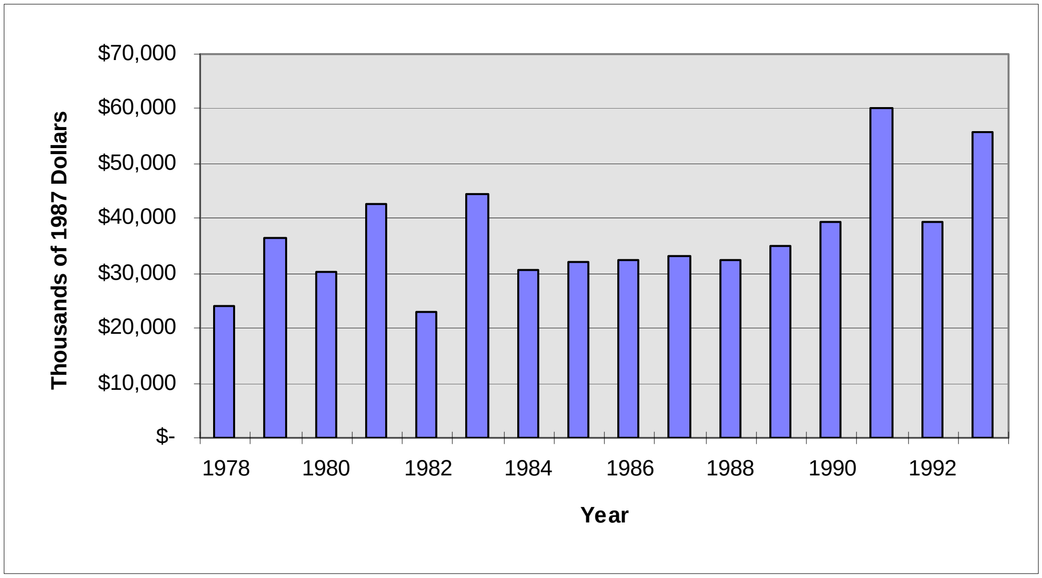
Miscellaneous Non-Building Construction Spending by County: Annual Averages 1978 - 1993

County	*Thousands of 1987 $*
Baker	2,567.9
Benton	7,338.9
Clackamas	33,600.2
Clatsop	29,173.7
Columbia	9,511.8
Coos	26,373.6
Crook	938.1
Curry	13,914.7
Deschutes	12,283.1
Douglas	13,700.8
Gilliam	3,393.8
Grant	449.6
Harney	1,399.6
Hood River	2,690.5
Jackson	28,350.6
Jefferson	1,281.9
Josephine	5,801.8
Klamath	11,085.8
Lake	1,279.9
Lane	72,057.5
Lincoln	21,674.7
Linn	6,523.3
Malheur	1,033.5
Marion	25,414.7
Morrow	2,202.1
Multnomah	152,741.8
Polk	2,608.1
Sherman	852.3
Tillamook	11,508.7
Umatilla	6,973.3
Union	1,428.3
Wallowa	1,623.6
Wasco	5,108.6
Washington	68,349.4
Wheeler	319.6
Yamhill	5,193.9
Total	590,750

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -18

Oregon Miscellaneous Non-Building Construction
Thousands of 1987 Dollars



Source: FW Dodge.

Bridges

Bridge construction is reported by FW Dodge in thousands of dollars. The data were adjusted for inflation and are shown in thousands of 1987 dollars in the model. Contained in this category are railroad, pedestrian, and vehicle bridges. It encompasses new construction as well as major repair projects. The amount of aggregate used on bridge projects varies widely. One of the most intense uses occurs in highway exit and overpass construction. For these, besides the need for aggregate in base rock and cement, large amounts are consumed for fill and embankment materials.

According to our 50-year forecast, 1.4% of the aggregate used in Oregon will go into bridge projects. Historically, bridge construction takes place in all 36 counties. How much occurs in each of them depends upon both the growth of the county and its geography. Spending on bridges tends to be high in counties with major cities that span large waterways. This why Lincoln, Coos, and Polk Counties show above average levels of bridge construction on Table Chapter Two -17.

The equation used to forecast bridge construction by county is simply tied to the number of households. The adjustment factor plays a major role in the forecast. It accounts for geographic differences in the counties which cannot be readily estimated in an econometric analysis. Dummy variables that identified counties with major waterways were tried and they had some significance. Not all counties with major waterways, however, have urban areas that span them.

Equation (40) is a regression of bridge construction versus the number of households in a county. It was found that the best correlation between these two variables happens when they are in a natural logarithm form. This is because the amount of bridge construction rises, but at a slowing rate, as the number of households increases. The R^2 of regression equation (40) is 0.65 and the T-statistic of the coefficient for the household variable is 8.0.

In the model, the regression equation is transformed so that it forecasts construction in thousands of 1987 dollars rather than the natural logarithm. This transformed version is shown below as equation (41).

The bridge construction equations are:

(40) $Ln(BRI_{C,T}) = -1.19961 + 0.788668 * Ln(HH_{C,T})$

(41) $BRI_{C,T} = (10/9) * e^{(-1.19961 + 0.788668 * Ln(HH_{C,T}))} * CAFBRI_C$

(42) $ABRI_{C,T} = BRI_{C,T} * (AFBRI_C * CPFBRI) * TECH_T$

Where:

Ln is the natural logarithm of an expression. It equals the value of the expression in base e (defined below) and is widely used in equations where natural compound growth is a factor.

$BRI_{C,T}$ is the amount of bridge construction spending occurs in a county for a specific year. It is in terms of thousands of 1987 dollars.

$HH_{C,T}$ equals the number of households living in a county in a given year.

e equals approximately 2.718282 and is the base used in natural logarithms.

$CAFBRI_C$ is the county adjustment factor for bridge construction. It equals the ratio of the historical actual and fitted values of this equation.

$ABRI_{C,T}$ equals the tons of aggregate used for bridges in a county for a given year.

$AFBRI_C$ is the amount of aggregate used at bridge construction sites for every thousand 1987 dollars spent. It is set to eight tons in eastern Oregon and 10 tons in western Oregon.

CPFBRI is the amount of aggregate contained in precast concrete and other finished concrete products used in bridge construction. It is set to 1.28 tons per thousand 1987 dollars.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -17

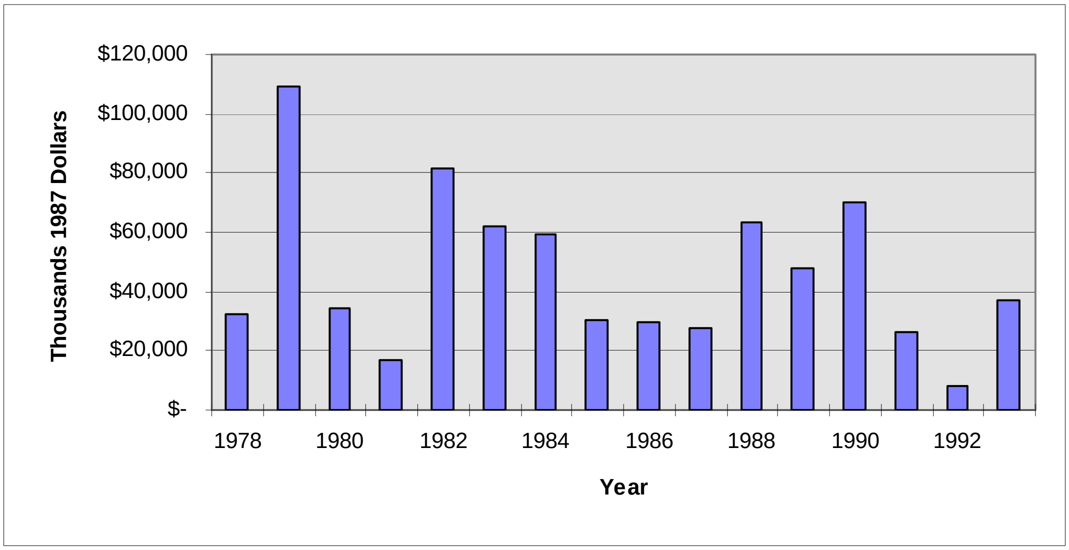
Bridge Construction Spending by County
Annual Averages 1978 - 1993

County	*Thousands of 1987 $*
Baker	4,801
Benton	1,622
Clackamas	16,409
Clatsop	20,045
Columbia	7,051
Coos	34,190
Crook	2,661
Curry	6,457
Deschutes	5,889
Douglas	24,542
Gilliam	2,036
Grant	2,598
Harney	1,539
Hood River	4,508
Jackson	10,016
Jefferson	2,935
Josephine	16,735
Klamath	18,804
Lake	871
Lane	47,750
Lincoln	65,319
Linn	26,093
Malheur	7,450
Marion	31,530
Morrow	3,289
Multnomah	235,988
Polk	49,565
Sherman	1,523
Tillamook	13,858
Umatilla	15,255
Union	9,067
Wallowa	2,124
Wasco	1,436
Washington	39,026
Wheeler	503
Yamhill	3,441
Total	736,924

Source: FW Dodge data modified by DOGAMI.

Figure Chapter Two -19

Oregon Bridge Construction Spending
Thousands of 1987 Dollars



Source: FW Dodge.

River and Marine

River and marine construction includes work on ports, docks, marinas, piers, dredging, and shoreline maintenance. It is measured in thousands of 1987 dollars. Some of this activity requires the use of large quantities of aggregates while others may use no aggregate at all. In total, about 0.6% of all the forecast aggregate consumption will go into river and marine construction.

Over 98% of the river and marine construction from 1978 to 1993 occurred in the 14 counties that have ports. Multnomah County, which has the state's largest port, accounted for 55% of all the spending in this category. Of the 22 counties with no ports, 10 reported small amounts of river and marine construction. Most of this was for recreational boating and floating home facilities.

The regression equation used in the model employs a county's real personal income times a dummy variable. The dummy variable is set to one for counties with a port authority and zero for those that do not have one. This equation has an R^2 of 0.92 and a T-statistic of 19.5 for the independent variable's coefficient.

The river and marine construction equations are:

(43) $RIVMAR_{C,T} = (10/9) * (3.85924 + 0.001222 * (DVARPORT_C * PI_{C,T}) + CAFRIVMAR_C)$

(44) $ARIVMAR_{C,T} = RIVMAR_{C,T} * (AFRIVMAR_C * CPFRIVMAR) * TECH_T$

Where:

$RIVMAR_{C,T}$ is the value of river and marine construction in a county for a specified year.

$DVARPORT_C$ is a dummy variable that equals one if the county has a port authority and zero if it does not. The counties with port authorities are italicized on Table Chapter Two -18.

$PI_{C,T}$ is the total real personal income in a county for a specified year. It is in terms of thousands of 1987 dollars.

$CAFRIVMAR_C$ is the county adjustment factor for river and marine construction. It equals the difference between the historical actual and fitted values of this equation.

$ARIVMAR_{C,T}$ equals the tons of aggregate used for river and marine in a county for a given year.

$AFRIVMAR_C$ is the amount of aggregate used on river and marine construction sites for every thousand 1987 dollars spent. It is set to 6.6 tons in eastern Oregon and 7.8 tons in western Oregon.

CPFRIVMAR is the amount of aggregate contained in precast concrete and other finished concrete products used in river and marine construction. It is set to 0.564 tons per thousand 1987 dollars.

$TECH_T$ is the statewide technology factor for the forecast year.

Table Chapter Two -18

River and Marine Construction Spending by County
Annual Averages 1978 - 1993

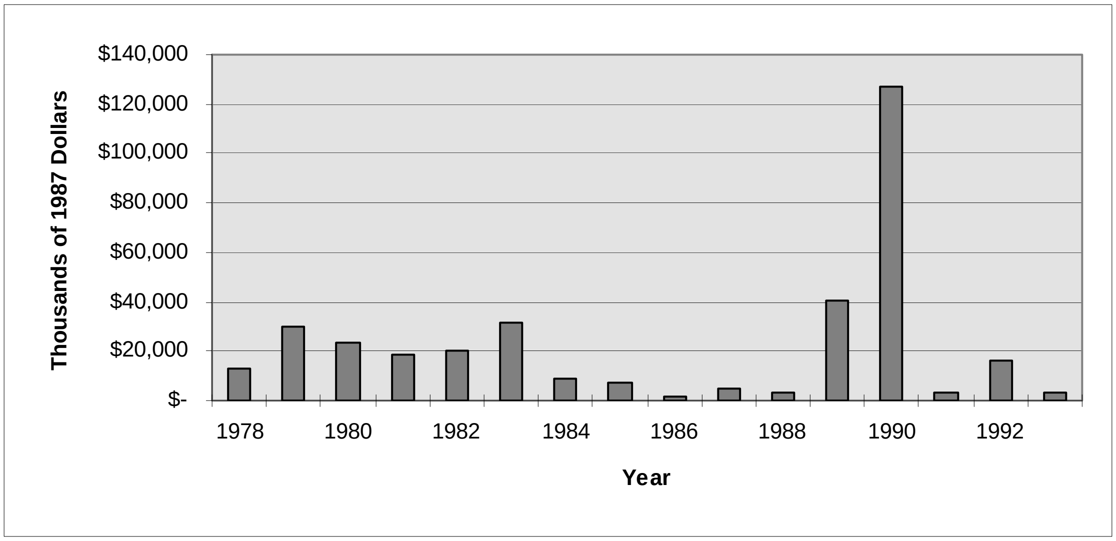
County	*Thousands of 1987 $*
Baker	265
Benton	542
Clackamas	1,233
Clatsop	*14,915*
Columbia	*960*
Coos	*30,904*
Crook	0
Curry	213
Deschutes	0
Douglas	*28,358*
Gilliam	*255*
Grant	197
Harney	0
Hood River	*1,268*
Jackson	2,896
Jefferson	0
Josephine	0
Klamath	0
Lake	0
Lane	*30,752*
Lincoln	*10,229*
Linn	218
Malheur	0
Marion	811
Morrow	*752*
Multnomah	*194,762*
Polk	606
Sherman	56
Tillamook	*32,519*
Umatilla	*658*
Union	0
Wallowa	0
Wasco	*0*
Washington	0
Wheeler	0
Yamhill	50
Total	353,419

Note: Counties with port authorities are italicized.

Sources: 1995 Oregon Blue Book and
FW Dodge data modified by DOGAMI.

Figure Chapter Two -20

Oregon River and Marine Construction Spending
Thousands of 1987 Dollars



Source: FW Dodge data modified by DOGAMI.

Housing

The housing section of the model is complicated because many factors come into play when forecasting new housing construction. Besides the obvious influence of population growth, we have to consider the effect of vacant units, conversions of old units, movements of households from temporary units and into permanent one, the need for vacation homes, and the abandonment of old housing.

Housing includes occupied, vacant, and seasonal residential units. Housing is measured in units. Each one can be the residence of one household. Single family units cover site-built homes, manufactured homes, and mobile homes. In the model, apartments, attached housing, two family homes, and condominiums are classified as multifamily units. These are divided into high-rise (over five units and at least four stories high) and low-rise units.

The model also has to account for other types of housing for families that are homeless or live in campers, recreational vehicles, floating homes, and boats. Group living arrangements, such as dormitories, jails, homeless shelters, hospitals, motels, and half-way houses, are not considered housing. They are forms of non-residential buildings that are captured elsewhere in the model.

New housing is built in a county for seven basic reasons:

1. To accommodate households that move into the county.
2. To accommodate new households that are formed in the county because of children moving out of their parents' homes, people moving out of group living environment, or because of families breaking up.
3. The need for more vacation, recreational, and seasonal housing. Included in these are cabins, large vacation homes, condominium units on the Oregon coast, and seasonal housing for farm workers.
4. In order to replace old housing that has become obsolete, uninhabitable, or undesirable.
5. To replace housing units that have been converted to commercial uses such as offices or stores.
6. To add to the stock of vacant housing.
7. To accommodate households in the county who move into constructed units from non-constructed units such as floating homes, campers, and homeless situations.

Housing Census data, which is collected only once every ten years, is the primary information source for this section of the model. It was supplemented with residential construction statistics from FW Dodge and building permit data. Regression equations for variables such as vacancy rates and housing losses had to be developed using Census data for the years 1990 and 1980. Wide swings in the housing markets occurred in Oregon's counties in between those years. In addition, the quality of the Census data also changed. The census, for instance, incorrectly classified a mobile home park in 1980 as an apartment building. They changed their survey methods in 1990 to better capture homeless households and classification errors which occurred in 1980. All this created serious problems for the regression estimation process because it normally relies on consistent time series data. Some of the housing equations, therefore, use assumed cause and effect relationships which we believe are reasonable. In some cases, regressions using housing data for 1990, or 1990 and 1980 were used in the model. A few equations employ if statements that capture any extreme changes in variables, such as a sudden drop in population.

The housing forecast is driven by the change in the number of households, the need for seasonal housing, and vacancy levels. The simplest variable to predict is the number of occupied housing units in a county. By definition, it equals the number of households (Equation 45).

(45) $HUOCC_{C,T} = HH_{C,T}$

Where:

$HUOCC_{C,T}$ is the number of occupied housing units in a county at the end of a given year.

$HH_{C,T}$. equals the number of households living in a specific county in a given year.

The part of the model which predicts the need for net additions to seasonal housing is shown below as equation (46). It is based upon historical patterns. In 1990, there were approximately 27 seasonal units for every 1,000 households in the state. Historically, this ratio has been rising and is predicted here to increase to 37 by the year 2050. It is assumed each county will get a fixed share of the new seasonal housing built in Oregon. These forecast shares of new seasonal units are shown on Table Chapter Two - 19.

(46) $HUSEAS_{C,T} = (HHOR_{C,T} - HHOR_{C,T-1}) * PSNVH_{C} * PVHORE_{T} + HUSEAS_{C,T-1}$

Where:

$HUSEAS_{C,T}$ equals the number of seasonal housing units in a county at the end of a given year.

$HHOR_{T}$ is the number of households in Oregon for the year specified.

$PSNVH_{C}$ equals the expected share of all net additions in seasonal housing in Oregon that will go into the specified county each year in the forecast.

$PVHORE_{T}$ is the ratio of seasonal units to households for the entire state by year.

Table Chapter Two -19

Share of Oregon's Stock of Seasonal Housing by County
1993 Estimates and Forecast of Shares of New Units Added from 2001 to 2050

County	*Estimated 1993 Share*	*Forecast Share of New Units*
Baker	2.17%	3.40%
Benton	0.35%	0.25%
Clackamas	5.66%	2.40%
Clatsop	8.98%	9.00%
Columbia	0.29%	0.50%
Coos	2.22%	3.60%
Crook	0.82%	2.60%
Curry	2.68%	4.00%
Deschutes	15.34%	12.75%
Douglas	1.51%	2.00%
Gilliam	0.21%	0.25%
Grant	0.99%	1.40%
Harney	0.51%	0.70%
Hood River	0.48%	2.70%
Jackson	1.70%	1.60%
Jefferson	4.23%	4.70%
Josephine	1.27%	1.20%
Klamath	4.65%	2.50%
Lake	0.76%	0.90%
Lane	5.58%	4.30%
Lincoln	15.49%	12.50%
Linn	0.59%	0.50%
Malheur	0.90%	1.20%
Marion	1.34%	0.80%
Morrow	0.54%	0.50%
Multnomah	1.65%	1.20%
Polk	0.06%	0.25%
Sherman	0.05%	0.35%
Tillamook	12.06%	12.25%
Umatilla	1.05%	1.90%
Union	0.88%	1.25%
Wallowa	2.12%	3.50%
Wasco	1.74%	2.10%
Washington	0.60%	0.40%
Wheeler	0.29%	0.30%
Yamhill	0.23%	0.25%
Total	100.00%	100.00%

Vacant housing is calculated as an identity using equation (47) below.

(47) $HUEMPT_{C,T} = HU_{C,T} - HUOCC_{C,T} - HUSEAS_{C,T}$

Where:

$HUEMPT_{C,T}$ equals the number of vacant units of single family homes, manufactured homes, and multifamily homes.

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

$HUOCC_{C,T}$ is the number of occupied housing units in a county at the end of a given year. It equals the number of households in the county.

$HUSEAS_{C,T}$ equals the number of seasonal housing units in a county at the end of a given year.

The number of single family units in a county is derived by adding new construction and subtracting lost housing from the number of single family units that existed at the beginning of a year. This I shown as equation (48).

(48) $SFU_{C,T} = SFU_{C,T-1} + SFUADD_{C,T} + SFLOSS_{C,T}$

Where:

$SFU_{C,T}$ equals the number of single family site built homes that exist in a county at year end. It includes occupied, vacant, and seasonal units.

$SFUADD_{C,T}$ is the gross number of new site-built single family housing units built in a county during a specific year.

$SFLOSS_{C,T}$ is the gross number of site-built single family homes that were lost in the county during the year. Losses occur when houses are converted into multifamily units and commercial business places. Losses also happen when homes are torn down (even if a new home replaces the old one), permanently abandoned, or are uninhabitable.

The number of multifamily units is calculated the same way. The number of units lost during the year are subtracted from the number of new units built. This total is added to the number of multifamily units that were in existence at the bringing of the year.

(49) $MFU_{C,T} = MFU_{C,T-1} + MFUADD_{C,T} + MFLOSS_{C,T}$

Where:

$MFU_{C,T}$ equals the number of multifamily housing units that exist in a county at year end. A multifamily unit is part of a larger building. A single building has at least two units in it. This category encompasses occupied, vacant, and seasonal units.

$MFUADD_{C,T}$ is the gross number of new multifamily housing units built in a county during a specific year.

$MFLOSS_{C,T}$ is the gross number of multifamily housing units lost in the county during a year. Losses occur when units are converted into other uses, are torn down, permanently abandoned, or become uninhabitable.

The same technique is used for manufactured housing in equation (50).

(50) $MANU_{C,T} = MANU_{C,T-1} + MANUADD_{C,T} + MANLOSS_{C,T}$

Where:

$MANU_{C,T}$ equals the number of manufactured homes in a county at year end. This does not include motorized homes or light trailers. This category encompasses occupied, vacant, and seasonal units.

$MANUADD_{C,T}$ is the gross number of manufactured homes put in place in the county for a specific year.

$MANLOSS_{C,T}$ is the gross number of manufactured homes lost in the county during a year. Losses occur when units are moved out of the county, replaced, torn down, permanently abandoned, or become uninhabitable.

Other housing encompasses households that are homeless or that live in campers, motorized homes, floating homes, or other non-traditional housing. Equation (51) is used in the model to forecast this category. It extrapolates the percentage of all households in each county that live in the “other” housing from actual data for 1993 and a forecast for 2050 that is entered in the model as an external constant. The 1993 and 2050 percentages for each county are listed in Table Chapter Two -20.

(51) $HUOTH_{C,T} = HH_{C,T} * (HUOTH_{C,T=1993} / HH_{C,T=1993}) * (2050 - YEAR_T) / 57 + HH_{C,T} * OTH_C * (YEAR_T - 1993) /57$

Where:

$HUOTH_{C,T}$ is the number of households who are homeless or live in non-constructed housing such as floating homes, boats, recreation vehicles, campers, motorized homes, light trailers, or tents. It does not include people living in group homes or shelters.

$HH_{C,T}$. equals the number of households living in a specific county in a given year.

YEAR is the forecast year.

OTH_C is the expected portion of households who will be homeless or living in non-constructed housing in the year 2050 in the county specified.

Table Chapter Two -20

Other Housing as a Percentage of Total Housing by County for 1993 with a Forecast for 2050

County	*% Other Housing 1993*	*% Other Housing Predicted 2050*
Baker	10.9%	3.09%
Benton	2.1%	2.39%
Clackamas	2.7%	1.70%
Clatsop	8.6%	2.39%
Columbia	3.4%	3.09%
Coos	7.3%	6.00%
Crook	6.0%	4.00%
Curry	6.4%	6.00%
Deschutes	5.6%	2.39%
Douglas	4.5%	3.09%
Gilliam	26.9%	2.39%
Grant	12.2%	4.00%
Harney	12.1%	4.00%
Hood River	12.7%	4.00%
Jackson	2.7%	3.09%
Jefferson	4.4%	6.00%
Josephine	5.2%	3.09%
Klamath	7.8%	1.70%
Lake	16.0%	6.00%
Lane	3.0%	1.70%
Lincoln	7.7%	6.00%
Linn	3.3%	2.39%
Malheur	8.1%	0.93%
Marion	3.0%	2.39%
Morrow	12.9%	1.70%
Multnomah	3.4%	0.93%
Polk	4.0%	0.93%
Sherman	11.7%	4.00%
Tillamook	8.0%	4.00%
Umatilla	6.9%	0.93%
Union	6.2%	0.93%
Wallowa	13.5%	1.70%
Wasco	14.5%	3.09%
Washington	2.9%	0.93%
Wheeler	16.5%	6.00%
Yamhill	3.1%	1.70%

Equation (52) calculates the total number of housing units in each county. For counties where the number of households is falling, the total number of units declines 0.5%. This is approximately equal to what occurred in Oregon counties whose household counts fell from 1980 to 1990. In other cases the number of units equals the sum of occupied, seasonal, and vacant housing. The amount of vacant housing, however, varies depending upon how fast the county grows. For counties where the number of households increases more than one percent during the year, the vacancy rate equals 80 percent of the past year's rate plus 20 percent of a 5.8 percent vacancy rate. The normal vacancy rate in the state is 5.8 percent. The vacancy rate is the percent of all housing units that are vacant (seasonal housing is considered occupied). For slow growth counties whose household counts are rising less than one percent, 20 percent of vacancy rates between 6.8 and 5.8 percent are used.

Figure Chapter Two -21is a graph of the vacancy rates for Oregon's 36 counties in 1990. These are plotted against the percent change in the number of households in each county from 1989 to 1990. Statewide, 1990 was a good year for the economy. Residential real estate markets in most counties were strong. The number of households in Oregon rose 2.39 percent in 1990 and the average vacancy rate was only 5.06 percent.

As can be seen from the figure, there is a negative relationship between household growth and vacancy rates. Counties with high growth in the number of households tend to have low vacancy rates. This is reflected in the significant negative correlation of -0.53 between household growth and vacancy rate data from Figure Chapter Two -21.

(52) $HU_{C,T}$ = if { ($HH_{C,T}$ - $HH_{C,T-1}$) < 0 } then 0.995 * $HU_{C,T-1}$ else ($HUSEAS_{C,T}$ + $HUOCC_{C,T}$) / { 1 - (0.8 * $HUEMPT_{C,T-1}$ / $HU_{C,T-1}$ + 0.2 * (0.058 - 1.0375 * [if { ($HH_{C,T}$ - $HH_{C,T-1}$)/ $HH_{C,T-1}$ } < 0.01 then ($HH_{C,T}$ - $HH_{C,T-1}$)/ $HH_{C,T-1}$ -0.01 else 0]

Where:

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

$HH_{C,T}$. equals the number of households living in a specific county in a given year.

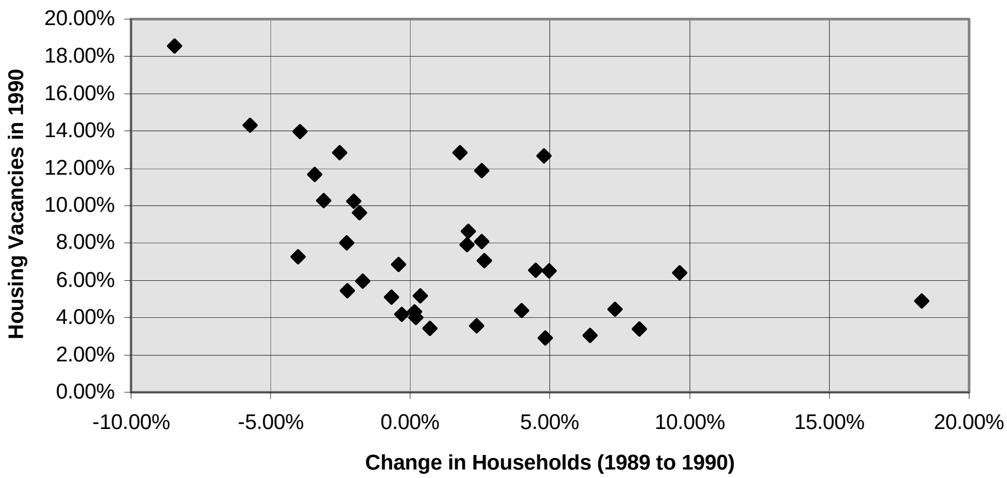
$HUSEAS_{C,T}$ equals the number of seasonal housing units in a county at the end of a given year.

$HUOCC_{C,T}$ is the number of occupied housing units in a county at the end of a given year. It equals the number of households in the county.

$HUEMPT_{C,T}$ equals the number of vacant units of single family homes, manufactured homes, and multifamily homes.

Figure Chapter Two -21

1990 County Vacancy Rates Versus Household Growth Rates



The annual loss of single family site-built homes is computed using equation (53). It is based upon a regression of the annual loss rate from 1980 to 1990 versus the average of the vacancy rates for 1980 and 1990. The R^2 of the equation was 15.3 and the T-statistic of the independent variable's coefficient was significant at 2.5. The regression equation was transformed into the equation below which yields the annual loss in number of units.

According to the equation, for a county with a very low vacancy rate of 2.0%, one single family site-built house out of every 215 is lost each year. For counties with a normal vacancy rate of 5.8%, the loss rate is higher. One out of every 159 homes is lost. In a county with a high vacancy rate of 15.0%, one out of 98 single family site-built homes is lost.

(53) $SFLOSS_{C,T} = SFU_{C,T-1} * (0.003806 + 0.042799 * HUEMPT_{C,T-1} / HU_{C,T-1})$

Where:

$SFLOSS_{C,T}$ is the gross number of site-built single family homes that were lost in the county during the year. Losses occur when houses are converted into multifamily units and commercial business places. Losses also happen when homes are torn down (even if a new home replaces the old one), permanently abandoned, or are uninhabitable.

$SFU_{C,T}$ equals the number of single family site built homes that exist in a county at year end. It includes occupied, vacant, and seasonal units.

$HUEMPT_{C,T}$ equals the number of vacant units of single family homes, manufactured homes, and multifamily homes.

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

Equation (54) calculates the annual loss of multifamily housing. Multifamily housing is more sensitive to vacancies than single family homes. Multifamily housing depreciates faster and has a shorter life expectancy than single family housing. Like the previous equation, equation (54) is based upon a regression of the annual loss rate from 1980 to 1990 and the average of the vacancy rates for 1980 and 1990. The R^2 was 35.3 with a T-statistic of 4.3 for the coefficient of the independent variable. The regression equation was transformed for ease of use in the model by having it calculate the annual loss in number of units rather than as a percentage of total units.

In a county with a low 2.0% vacancy rate, one out of every 148 multifamily units is lost in a year. If the vacancy rate is at the normal level of 5.8%, one out of every 77 units will be lost. In the extreme case of a 15.0% vacancy rate, the losses rise to one out of 36.

$$(54)\ MFLOSS_{C,T} = MFU_{C,T-1} * (0.003489 + 0.16341 * HUEMPT_{C,T-1} / HU_{C,T-1})$$

Where:

$MFLOSS_{C,T}$ is the gross number of multifamily housing units lost in the county during a year. Losses occur when units are converted into other uses, are torn down, permanently abandoned, or become uninhabitable.

$MFU_{C,T}$ equals the number of multifamily housing units that exist in a county at year end. A multifamily unit is part of a larger building. A single building has at least two units in it. This category encompasses occupied, vacant, and seasonal units.

$HUEMPT_{C,T}$ equals the number of vacant units of single family homes, manufactured homes, and multifamily homes.

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

Data on manufactured housing is particularly poor. It appears that some people filling out Census forms incorrectly classified manufactured homes. The Oregon Department of Motor Vehicles (DMV) tracks the net number of manufactured homes put-in-place, but in recent years their figures have diverged significantly from what is reported by producers of manufactured homes. Based on census population figures, housing balances using FW Dodge construction data, and conversation with county governments, it was clear that the DMV and Census data under estimated the number of units. For this reason, it was not possible to use a regression analysis on the loss rate for manufactured housing. Instead, we simply use a loss rate equal to 150% of the rate for site-built single family houses. This is shown in equation (55).

$$(55)\ MANLOSS_{C,T} = MANU_{C,T-1} * 1.5 * (0.003806 + 0.042799 * HUEMPT_{C,T-1} / HU_{C,T-1})$$

Where:

$MANLOSS_{C,T}$ is the gross number of manufactured homes lost in the county during a year. Losses occur when units are moved out of the county, replaced, torn down, permanently abandoned, or become uninhabitable.

$MANU_{C,T}$ equals the number of manufactured homes in a county at year end. This does not include motorized homes or light trailers. This category encompasses occupied, vacant, and seasonal units.

$HUEMPT_{C,T}$ equals the number of vacant units of single family homes, manufactured homes, and multifamily homes.

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

The number of units that must be constructed is calculated using equation (56). It is an identity equation. Construction equals the change in the total number of units plus any losses during the year. Excluded in the equation is “other housing” which does not require much, if any, construction.

(56) $HUCON_{C,T} = HU_{C,T} - HUOTH_{C,T} + (SFLOSS_{C,T} + MFLOSS_{C,T} + MANLOSS_{C,T}) - (SFU_{C,T-1} + MFU_{C,T-1} + MANU_{C,T-1})$

Where:

$HUCON_{C,T}$ equals the number of new housing units that must be constructed. This includes single family homes, multifamily homes, and the putting in-place of manufactured homes.

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

$HUOTH_{C,T}$ is the number of households who are homeless or live in non-constructed housing such as floating homes, boats, recreation vehicles, campers, motorized homes, light trailers, or tents. It does not include people living in group homes or shelters.

$SFLOSS_{C,T}$ is the gross number of site-built single family homes that were lost in the county during the year. Losses occur when houses are converted into multifamily units and commercial business places. Losses also happen when homes are torn down, permanently abandoned, or are uninhabitable.

$MFLOSS_{C,T}$ is the gross number of multifamily housing units lost in the county during a year. Losses occur when units are converted into other uses, are torn down, permanently abandoned, or become uninhabitable.

$MANLOSS_{C,T}$ is the gross number of manufactured homes lost in the county during a year. Losses occur when units are moved out of the county, replaced, torn down, permanently abandoned, or become uninhabitable.

$SFU_{C,T}$ equals the number of single family site built homes that exist in a county at year end. It includes occupied, vacant, and seasonal units.

$MFU_{C,T}$ equals the number of multifamily housing units that exist in a county at year end. A multifamily unit is part of a larger building. A single building has at least two units in it. This category encompasses occupied, vacant, and seasonal units.

$MANU_{C,T}$ equals the number of manufactured homes in a county at year end. This does not include motorized homes or light trailers. This category encompasses occupied, vacant, and seasonal units.

Equation (57) calculates that part of housing construction needed for the expansion of households who move into site-built, manufactured, and multifamily housing

(57) $HUCONEX_{C,T} = HU_{C,T} - HU_{C,T-1} - HUOTH_{C,T} + HUOTH_{C,T-1}$
with $HUCONEX_{C,T}$ having a minimum value of zero.

Where:

$HUCONEX_{C,T}$ equals the number of new housing units that must be constructed to accommodate the increase in households in a county during the year specified. This is one part of the housing that may be built in a county. In addition to this, there may be a need for new construction to replace obsolete housing.

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

$HUOTH_{C,T}$ is the number of households who are homeless or live in non-constructed housing such as floating homes, boats, recreation vehicles, campers, motorized homes, light trailers, or tents. It does not include people living in group homes or shelters.

Equation (58) calculates that part of housing construction done that replaces losses in site-built, manufactured, and multifamily housing

(58) $HUCONRE_{C,T} = HUCON_{C,T} - HUCONEX_{C,T}$

Where:

$HUCONRE_{C,T}$ equals the number of new housing units that must be constructed to replace pre-existing housing that has been lost in a county during the year specified.

$HUCON_{C,T}$ equals the number of new housing units that must be constructed. This includes single family homes, multifamily homes, and the putting in-place of manufactured homes.

$HUCONEX_{C,T}$ equals the number of new housing units that must be constructed to accommodate the increase in households in a county during the year specified.

The number of site-built single family homes constructed in a county is determined in equation (59). It is an identity which subtracts additions of manufactured and multifamily housing from the total number of units put in-place.

(59) $SFUADD_{C,T} = HUCON_{C,T} - MFUADD_{C,T} - MANUADD_{C,T}$

Where:

$SFUADD_{C,T}$ is the gross number of new site-built single family housing units built in a county during a specific year.

$HUCON_{C,T}$ equals the number of new housing units that must be constructed. This includes single family homes, multifamily homes, and the putting in-place of manufactured homes.

$MFUADD_{C,T}$ is the gross number of new multifamily housing units built in a county during a specific year.

$MANUADD_{C,T}$ is the gross number of manufactured homes put in place in the county for a specific year.

Equation (60) computes multifamily housing construction. The percentage of all housing units that are multifamily is correlated to urban household density. Urban household density equals the number of households living in census blocks with fewer than 10 acres per family divided by the area of the county. Figure Chapter Two -22 shows the relationship between the urban density and the percent of units that are multifamily. Each item plotted on the figure is for one of the 36 counties in Oregon for the year 1990.

Equation (60) is based on a transformation of a regression equation. The regression forecasts the percentage of multifamily housing using urban household density as the independent variable. In the regression both variables are expressed in the forms of natural logarithms. The R^2 of the regression equation is 0.66 and the T-statistic for the independent variable is 8.1.

The regression is plotted on Figure Chapter Two -23 as a dashed line. It shows what percentage of the housing stock is multifamily for a given level of urban density in a county. In a county with an urban household density of 30 per square mile, 19.5% of the units in-place are multifamily. Equation (60), however, must forecast new construction. To do this, we need to know how much of the incremental new units are going to be multifamily. In other words, we have to estimate the first derivative of the regression with respect to the change in the number of households. This is shown as the solid line on Figure Chapter Two -23. In a county with a density of 30, it shows that 24.9% of the new units are multifamily.

$$(60)\ MFUADD_{C,T} = (HU_{C,T} - HU_{C,T-1} - HUOTH_{C,T} + HUOTH_{C,T-1}) * [\{ e^{[-2.57742 + 0.277256 * Ln (HH_{C,T} * URB_{C,T} / AREA_{C}) + MFADJ_{C} \}] * (HH_{C,T} - HUOTH_{C,T}) \}} - \{ e^{[-2.57742 + 0.277256 * \{ Ln (HH_{C,T} * URB_{C,T} / AREA_{C}) + MFADJ_{C} \}]} * (HH_{C,T} - 1 - HUOTH_{C,T}) \}] + MFLOSS_{C,T}$$

Where:

$SFUADD_{C,T}$ is the gross number of new site-built single family housing units built in a county during a specific year.

$MFUADD_{C,T}$ is the gross number of new multifamily housing units built in a county during a specific year.

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

$HUOTH_{C,T}$ is the number of households who are homeless or live in non-constructed housing such as floating homes, boats, recreation vehicles, campers, motorized homes, light trailers, or tents. It does not include people living in group homes or shelters.

e equals approximately 2.718282 and is the base used in natural logarithms.

Ln is the natural logarithm of an expression. It equals the value of the expression in base e (defined below) and is widely used in equations where natural compound growth is a factor.

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

$AREA_{C}$ equals the land area of a county in square miles.

$MFADJ_{C}$ is an adjustment factor used to calculate the portion of units built in a county that are multifamily.

$MFLOSS_{C,T}$ is the gross number of multifamily housing units lost in the county during a year. Losses occur when units are converted into other uses, are torn down, permanently abandoned, or become uninhabitable.

Figure Chapter Two -22

1990 Urban Density Versus Multifamily Share of Housing for Oregon's Counties

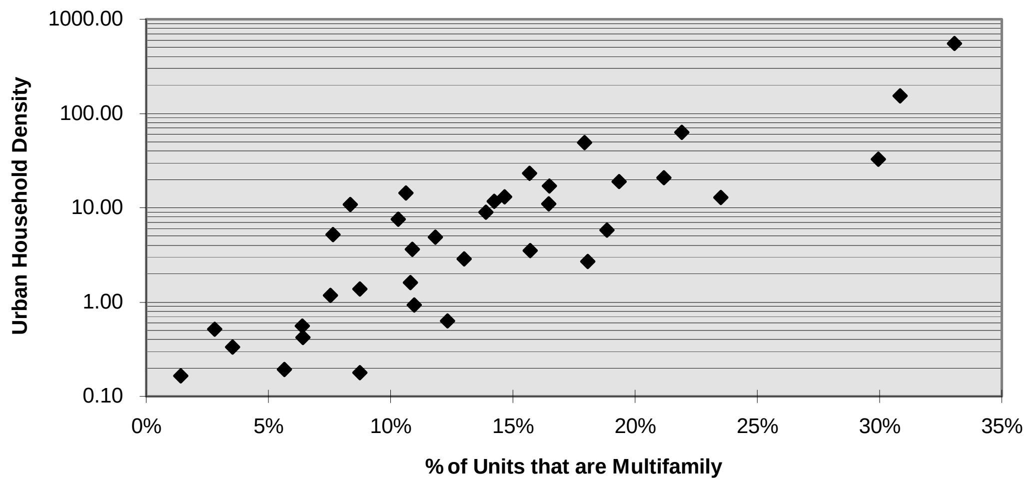
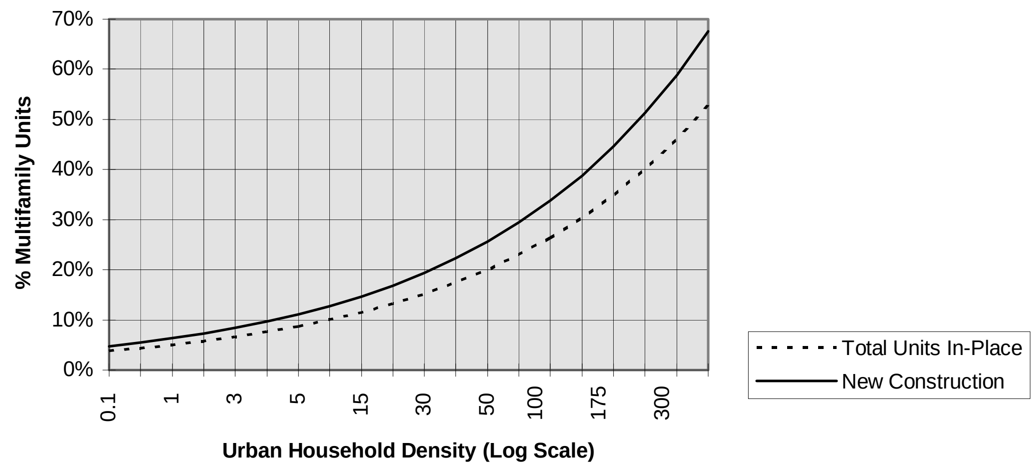


Figure Chapter Two -23

Relationship Between Household Density and Share of Multifamily Housing



Homes converted from single family to multifamily use make up some of the multifamily additions each year. The percentage of multifamily addition due to conversions is correlated with the natural log of a county's household density. The correlation coefficient between the two is 0.43. This relationship was used in the development of equation (61) below.

(61) $MFCONVR_{C,T} = MFUADD_{C,T} * \{ 0.011 + 0.03139 * Ln (1 + HHDEN_{C,T}) \}$

Where:

$MFCONVR_{C,T}$ is the number of multifamily units made out of single family homes in a county during a year. It includes both legal and illegal conversions.

$MFUADD_{C,T}$ is the gross number of new multifamily housing units built in a county during a specific year.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

Equation (62) is an identity used to forecast the number of low-rise multifamily units constructed in a county. It equals the total number of multifamily units built less conversions and new high-rise units.

(62) $MFLRUADD_{C,T} = MFUADD_{C,T} - MFCONVR_{C,T} - MFHRUADD_{C,T}$

Where:

$MFLRUADD_{C,T}$ is the gross number of new low-rise (three stories or less) multifamily housing units built in a county during a specific year.

$MFUADD_{C,T}$ is the gross number of new multifamily housing units built in a county during a specific year.

$MFCONVR_{C,T}$ is the number of multifamily units made out of single family homes in a county during a year. It includes both legal and illegal conversions.

$MFHRUADD_{C,T}$ is the gross number of new high-rise (four stories or more and at least five units in a building) multifamily housing units built in a county during a specific year.

Equation (63) is the first of a two part process to calculate the number of high-rise units built. This equation estimates the number of high rise units. If the result is at least twelve, then equation (64) uses it as the forecast for high-rise units. This two step process makes the modeling procedure simpler and it prevents a forecast of fewer than twelve high-rise units.

Equation (63) is based upon observations of multifamily construction by county for the 1978 to 1993 period. Since most counties reported no high-rise housing additions, there was insufficient data for doing a regression analysis. Equation (63) follows the relationship shown in Figure Chapter Two -24. For counties with less than 10 households per square mile, no high rises are added. Those with a density of exactly 50 and a gross addition of 600 units, 2% of the multifamily units added are high rises. If they added less than 600 units then the number of high rises would be less than 12. That result would be reduced to zero in equation (64). Twenty-five percent of the units are high rise in a county with a density of 500. Currently, only Multnomah County, which includes Portland , Oregon, has a density above 500.

(63) $PREHR_{C,T}$ = if ($HHDEN_{C,T} < 10$) then 0
if ($HHDEN_{C,T} >= 10 < 50$) then $(MFUADD_{C,T} - MFCONVR_{C,T}) * (HHDEN_{C,T} - 10) / 40 * 0.02$
if ($HHDEN_{C,T} >= 50 < 250$) then $(MFUADD_{C,T} - MFCONVR_{C,T}) * \{(HHDEN_{C,T} - 50) / 200 * .06 + 0.02 \}$
if ($HHDEN_{C,T} >= 250 < 500$) then $(MFUADD_{C,T} - MFCONVR_{C,T}) * \{(HHDEN_{C,T} - 250)/250 * 0.17+0.08\}$
if ($HHDEN_{C,T} >= 500$) then $(MFUADD_{C,T} - MFCONVR_{C,T}) * \{(HHDEN_{C,T} - 500) / 1500 * 0.50 + 0.25\}$

Where:

$PREHR_{C,T}$ is the preliminary estimate of the number of high-rise multifamily housing units needed to built in a county for a specific year.

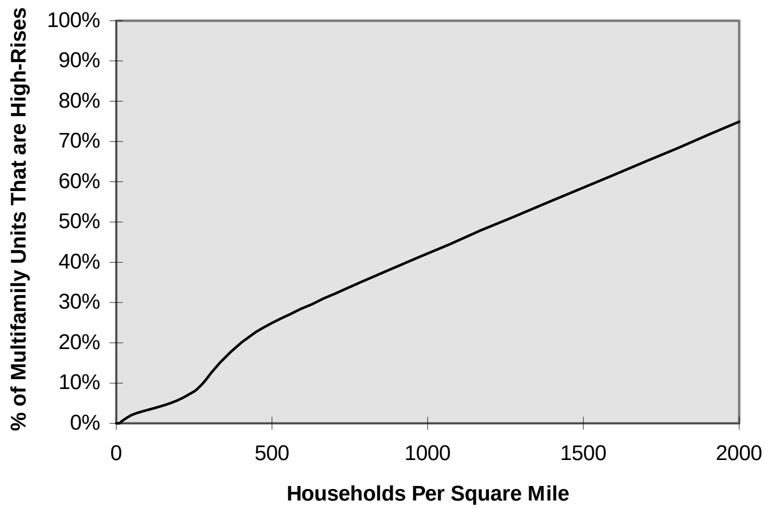
$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$MFUADD_{C,T}$ is the gross number of new multifamily housing units built in a county during a specific year.

$MFCONVR_{C,T}$ is the number of multifamily units made out of single family homes in a county during a year. It includes both legal and illegal conversions.

Figure Chapter Two -24

High-Rise Units as a Percent of Multifamily Construction Versus Household Density



Note: For counties with household densities under ten, 0% of the units are high-rises.

Equation (64) tests the preliminary estimate of high-rise units to see if it is at least 12. If it is then it becomes the forecast for high-rise unit additions.

(64) $MFHRUADD_{C,T}$ = if ($PREHR_{C,T}$ < 12) then 0 else $PREHR_{C,T}$
with $MFHRUADD_{C,T}$ having a value of zero, 12, or greater than 12.

Where:

$MFHRUADD_{C,T}$ is the gross number of new high-rise (four stories or more and at least five units in a building) multifamily housing units built in a county during a specific year.

$PREHR_{C,T}$ is the preliminary estimate of the number of high-rise multifamily housing units needed to built in a county for a specific year.

The number of manufactured homes added in a county is calculated in equation (65).It is based on a regression equation using county data for the 1980 to 1990 period. The dependent variable is the natural logarithm of the ratio of manufactured to all single family home additions. The independent variables are the natural logarithms of household density and personal income per capita. The R^2 of the regression is .84. The T-statistics are -16.5 and -3.2 respectively. This regression has been transformed in the model so that it forecast the level of manufactured home additions in one equation. A 16% factor was added to the equation because a recent State law change prohibits local communities from blocking manufactured housing. During the 1980s about one-third of the state had such laws and this dampened the market penetration of manufactured homes. The bulk of these areas were high density, high income areas where manufactured housing would be less popular than in the state as a whole. We estimate the penetration loss at 16%.

Statewide, manufactured housing has accounted for about 28% of the single family home additions. The percentage is higher in rural counties than in urban ones. This is reflected in the large negative T-statistic of the household density variable in the regression equation. Since manufactured homes are more popular with price sensitive consumers, there is also a negative relationship with personal income.

Table Chapter Two -21 is a ranking of Oregon's counties from the highest to least densely populated in terms of households. The table also lists manufactured housing's share of the single family home additions for the 1980 to 1993 period. Manufactured homes had a 27% share in the ten most densely populated counties. For the ten least densely populated, however, manufactured housing held a 61% share.

There are three reasons why manufactured housing takes a large share of the market in rural counties. Manufactured homes can only be one story high, thus they are less practical in places where land is expensive and multistory housing is preferred. Historically, many cities have had zoning laws which blocked the manufactured homes. The final reason is construction cost. Site-built homes can be very expensive in remote parts of Oregon where it is difficult to bring together labor, equipment, and materials and competitive prices. This is especially true for single unit construction.

(65) $MANUADD_{C,T} = (HUCON_{C,T} - MFUADD_{C,T}) * 1.16 * e^{[2.502355 - 0.28402 * Ln (1 + HHDEN_{C,T}) - 0.79354 * Ln (PIHH_{C,T} / 1000)]}$

Where:

$MANUADD_{C,T}$ is the gross number of manufactured homes put in place in the county for a specific year.

$HUCON_{C,T}$ equals the number of new housing units that must be constructed. This includes single family homes, multifamily homes, and the putting in-place of manufactured homes.

$MFUADD_{C,T}$ is the gross number of new multifamily housing units built in a county during a specific year.

e equals approximately 2.718282 and is the base used in natural logarithms.

Ln is the natural logarithm of an expression. It equals the value of the expression in base e (defined below) and is widely used in equations where natural compound growth is a factor.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$PIHH_{C,T}$ equals personal income per household, in 1987 dollars, for a county in a specified year.

Table Chapter Two -21

Share of Manufactured Homes in New Single Family Housing for Counties Ranked by Household Density 1980 to 1993 Averages

County	*Household Density*	*% of New Single Family Units That are Manufactured*
Multnomah	548.54	11.1%
Washington	149.29	9.5%
Marion	67.97	26.8%
Clackamas	50.64	23.2%
Benton	37.11	23.2%
Yamhill	29.28	33.1%
Polk	23.55	42.2%
Lane	23.37	36.4%
Columbia	20.61	40.0%
Jackson	19.40	28.3%
Lincoln	16.25	30.9%
Clatsop	15.98	23.5%
Linn	14.88	51.5%
Coos	14.70	42.5%
Josephine	14.70	31.5%
Hood River	12.13	38.3%
Deschutes	8.76	20.9%
Tillamook	7.95	29.0%
Douglas	6.90	49.5%
Umatilla	6.77	49.7%
Curry	4.70	42.8%
Union	4.39	37.8%
Klamath	3.76	50.2%
Wasco	3.57	55.9%
Jefferson	2.46	52.0%
Baker	2.03	52.4%
Crook	1.74	42.3%
Morrow	1.36	72.2%
Sherman	1.00	95.3%
Malheur	0.96	67.8%
Wallowa	0.89	45.0%
Grant	0.69	59.0%
Gilliam	0.61	67.6%
Wheeler	0.35	33.8%
Lake	0.34	59.9%
Harney	0.27	64.1%
State Total	11.02	27.7%

Equation (66) forecast the proportion of other housing additions which are motorized homes and recreation vehicles. Historically, this has been 72%. This form of housing does require the consumption of small amounts of aggregate.

(66) $RVADD_{C,T}$ = if ($HUOTH_{C,T}$ > $HUOTH_{C,T-1}$) then 0.72 * ($HUOTH_{C,T}$ - $HUOTH_{C,T-1}$) else 0
with $RVADD_{C,T}$ having a minimum value of zero.

Where:

$RVADD_{C,T}$ equals the net addition of households living in motorized homes, recreational vehicles, and light trailers.

$HUOTH_{C,T}$ is the number of households who are homeless or live in non-constructed housing such as floating homes, boats, recreation vehicles, campers, motorized homes, light trailers, or tents. It does not include people living in group homes or shelters.

The total number of square feet of site-built single family homes constructed in a county are calculated in equation (67). It is an identity equation that multiplies the total number of units constructed by the 1983 to 1993 average square footage for construction in the county. The average size of site-built homes was fairly stable until the mid-1980s when a large increase occurred. Square footage is unrelated to the density of a county, but is slightly correlated with personal income.

(67) $TSQFTSF_{C,T}$ = $AVGSFSQFT_{C}$ * $SFUADD_{C,T}$

Where:

$TSQFTSF_{C,T}$ equals the total square footage of site built single family homes constructed in a county for a given year.

$AVGSFSQFT_{C}$ is the average square footage of site-built single family homes in each county for the period from 1983 to 1993.

$SFUADD_{C,T}$ is the gross number of new site-built single family housing units built in a county during a specific year.

Aggregate use for single family homes depends, in large part, on the size of the foundation. The more densely populated a county is, the more likely its homes will be multi-story units. Multi-story homes have a smaller foundations than one story units of the same interior floor space. The model accounts for this with equation (68). Figure Chapter Two -25 shows the relationship between household density and foundation size for a typical 1,750 square foot site-built home in Oregon.

(68) $AVGSFFOUND_{C,T}$ = if ($HHDEN_{C,T}$ < 10) then $AVGSFSQFT_{C}$ * (1 - (0.09 * $HHDEN_{C,T}$ / 10))
if ($HHDEN_{C,T}$ => 10 and < 100) then $AVGSFSQFT_{C}$ * [0.91 - { 0.16 * ($HHDEN_{C,T}$ - 10) / 90 }]
if ($HHDEN_{C,T}$ => 100) then $AVGSFSQFT_{C}$ * [0.75 - { 0.295 * ($HHDEN_{C,T}$ - 100) / 1900 }]

Where:

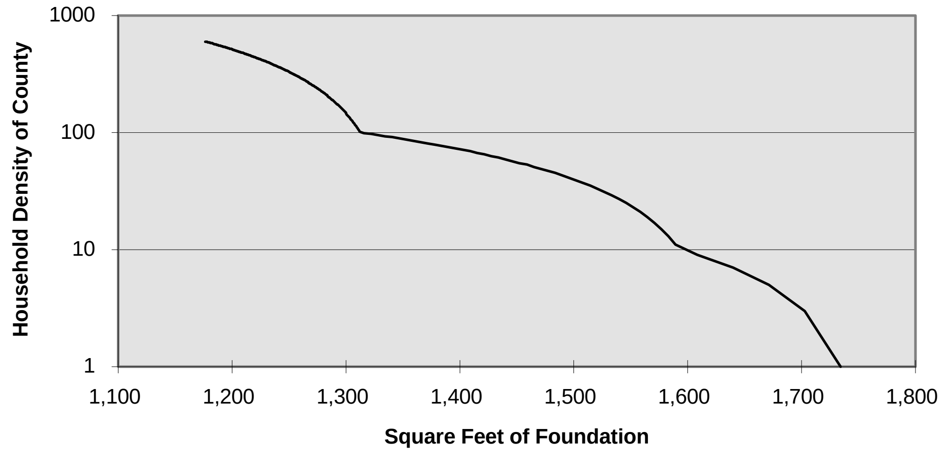
$AVGSFFOUND_{C,T}$ equals the average square feet of foundation in site-built single family homes constructed in a county for a given year.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$AVGSFSQFT_{C}$ is the average square footage of site-built single family homes in each county for the period from 1983 to 1993.

Figure Chapter Two -25

Foundation Area Versus County Household Density for a 1,750 Square Foot Site-Built Single Family Home



The total square footage of manufactured homes equals the number of units added times the average square footage. The average is set at 1,500 square feet in 1990 and increases by two square feet a year. This reflects a continuation of the current trend in manufactured housing.

(69) $TSQFTMAN_{C,T} = MANUADD_{C,T} * [1500 + 2 * (YEAR_{T} - 1990)]$

Where:

$TSQFTMAN_{C,T}$ equals the total square footage of manufactured housing put in place in a county for a given year.

$MANUADD_{C,T}$ is the gross number of manufactured homes put in place in the county for a specific year.

YEAR is the forecast year.

Equation (70) calculates the total square footage of low-rise multifamily units. The average per unit is set to 920 square feet. This is the historical average and it has been relatively stable for many years.

(70) $TSQFTLR_{C,T} = MFLRUADD_{C,T} * 920$

Where:

$TSQFTLR_{C,T}$ equals the total square footage of all the low-rise multifamily housing units built in a county during a given year.

$MFLRUADD_{C,T}$ is the gross number of new low-rise multifamily housing units built in a county during a specific year.

For high-rise multifamily units, additions are multiplied by 1,084 to give us the total square feet constructed. The recent historical average of 1,094 square feet is appropriate because the average unit size is not been trending up or down, nor does it appear related to population density or income levels.

$$(71)\ TSQFTHR_{C,T} = MFHRUADD_{C,T} * 1084$$

Where:

$TSQFTHR_{C,T}$ equals the total square footage of all the high-rise multifamily housing units built in a county during a given year.

$MFHRUADD_{C,T}$ is the gross number of new high- multifamily housing units built in a county during a specific year.

The amount of aggregate used to build a single family home varies widely depending on the style of the house and construction methods. Equation (72) estimates the amounts used on an average home. It factors in the foundation size, region of the state, and degree of urbanization.

A basic amount of 147.7 tons is used for each single family home. This material is used for site preparation, sidewalks, driveways, underground utilities, septic systems, walkways, drainage rock, and base rock. An additional 0.02 tons is added for the aggregate contained in cement used for each square foot of foundation. For perimeter footings, we assume that the typical building shape is rectangular and that 0.07 tons are needed for each linear foot. Perimeter footings and foundation cement add about 70 tons of aggregate to home construction. Rock used for staging areas and access roads in housing developments is estimated at 15 tons per unit in eastern Oregon and 45 tons in western Oregon. More rock is used in home construction in western Oregon because of the higher rainfall. The final factor in equation (72) attempts to capture the effect of higher aggregate use for private roads for rural houses.

$$(72)\ AFSF_{C,T} = 147.7 + 0.01172 * AVGSFFOUND_{C,T} + .07125 * \{ 6 * (AVGSFFOUND_{C,T} /2) \wedge 0.5 \} +15 * (1 + 2 * DWEST_{C}) + (1 - URB_{C,T}) *100$$

Where:

$AFSF_{C,T}$ is the tons of aggregate used in the construction of new site-built single family housing built in a county during the year.

$AVGSFFOUND_{C,T}$ equals the average square feet of foundation in site-built single family homes constructed in a county for a given year.

$DWEST_{C}$ is a dummy variable that equals one for western Oregon counties and zero for eastern Oregon counties.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

Total aggregate use for single family home construction in counties is calculated in equation (73). It is a simple identity.

$$(73)\ ASF_{C,T} = TECH_{T} * SFUADD_{C,T} * AFSF_{C,T} + TECH_{T} * SFU_{C,T-1} * RUSF$$

Where:

$ASF_{C,T}$ is the total amount of aggregate consumed in site-built single family housing construction. It include new housing and additions to old housing.

$TECH_{T}$ is the statewide technology factor for the forecast year.

$SFUADD_{C,T}$ is the gross number of new site-built single family housing units built in a county during a specific year.

$AFSF_{C,T}$ is the total square footage of new site-built single family housing built in a county during the year.

$SFU_{C,T}$ equals the number of single family site built homes that exist in a county at year end. It includes occupied, vacant, and seasonal units.

RUSF is the usage of aggregate for additions to pre-existing site-built single family homes. This equals 0.335 tons per house.

Equation (74) estimates the amount of aggregate used per manufactured home put-in-place. It is assumed that 0.03 tons are used for every square foot of floor space. Driveways, sidewalks, walkways, utilities, septic systems, curbs, and other site preparations add 108 tons. Site staging area and access roads are set to 10 tons per unit in eastern Oregon and 30 tons in western Oregon. A factor for longer private roads for rural homes is also included.

(74) $AFMAN_{C,T} = 0.03045 * (TSQFTMAN_{C,T} / MANUADD_{C,T}) + 108 + 10 * (1 + 2 * DWEST_{C}) + (1 - URB_{C,T}) *100$

Where:

$AFMAN_{C,T}$ equals the amount of aggregate used in the placing of a manufactured home in a county during the year. It includes the pad, driveway, underground utilities, sidewalk, temporary roads, and other features which require the use of aggregate.

$TSQFTMAN_{C,T}$ equals the total square footage of manufactured housing put in place in a county for a given year.

$MANUADD_{C,T}$ is the gross number of manufactured homes put in place in the county for a specific year.

$DWEST_{C}$ is a dummy variable that equals one for western Oregon counties and zero for eastern Oregon counties.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

The amount of aggregate used for manufactured single family homes is calculated in equation (75).

(75) $AMAN_{C,T} = TECH_{T} * MANUADD_{C,T} * AFMAN_{C,T} + TECH_{T} * MANU_{C,T-1} * RUMAN$

Where:

$AMAN_{C,T}$ is the total amount of aggregate consumed for putting in manufactured single family homes.

$TECH_{T}$ is the statewide technology factor for the forecast year.

$MANUADD_{C,T}$ is the gross number of manufactured homes put in place in the county for a specific year.

$AFMAN_{C,T}$ equals the amount of aggregate used in the placing of a manufactured home in a county during the year. It includes the pad, driveway, underground utilities, sidewalk, temporary roads, and other features which require the use of aggregate.

$MANU_{C,T}$ equals the number of manufactured homes in a county at year end. This does not include motorized homes or light trailers. This category encompasses occupied, vacant, and seasonal units.

RUMAN is the usage of aggregate for additions to pre-existing manufactured homes. It equals 0.47 tons.

Equation (76) estimates the amount of aggregate used in the construction of low-rise multifamily housing.

$$(76)\ ALR_{C,T} = TECH_T * MFLRUADD_{C,T} * (AFLR + CPFLR)$$

Where:

$ALR_{C,T}$ is the total amount of aggregate consumed in building new low-rise multifamily units in a county during a year.

$TECH_T$ is the statewide technology factor for the forecast year.

$MFLRUADD_{C,T}$ is the gross number of new low-rise multifamily housing units built in a county during a specific year.

AFLR is the amount of aggregate used in direct forms for building each unit of low-rise multifamily housing. It equals 96.4 tons in eastern and central Oregon. It is 136.4 tons in western Oregon where more aggregate is needed because of the greater rainfall.

CPFLR equals the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon for building each unit of low-rise multifamily housing. It equals about 23 tons.

Aggregate use in high-rise housing construction is calculated in equation (77).

$$(77)\ AHR_{C,T} = TECH_T * MFHRUADD_{C,T} * (AFHR + CPFHR)$$

Where:

$AHR_{C,T}$ is the total amount of aggregate consumed in building new high-rise multifamily units in a county during a year.

$TECH_T$ is the statewide technology factor for the forecast year.

$MFHRUADD_{C,T}$ is the gross number of new high-rise multifamily housing units built in a county during a specific year.

AFHR is the amount of aggregate used in direct forms for building each unit of high-rise multifamily housing. It equals 140.25 tons in eastern Oregon and 160.25 in western Oregon.

CPFLR equals the amount of aggregate indirectly used in the forms of masonry and finished concrete products in Oregon for building each unit of high-rise multifamily housing. It equals about 35 tons.

Aggregate used for building, and maintaining places for households living in motorized homes, and recreational vehicles is calculated in equation (78).

$$(78)\ ARV_{C,T} = TECH_T * RVADD_{C,T} * AFRV + TECH_T * HUOTH_{C,T-1} * 0.72 * RURV$$

Where:

$ARV_{C,T}$ is the total amount of aggregate consumed in providing a place for net addition of households living in motorized homes, recreational vehicles, and light trailers.

$TECH_T$ is the statewide technology factor for the forecast year.

$RVADD_{C,T}$ equals the net addition of households living in motorized homes, recreational vehicles, and light trailers.

AFRV is the amount of aggregate used in direct forms for building each unit of low-rise multifamily housing. It equals 86.3 tons.

$HUOTH_{C,T}$ is the number of households who are homeless or live in non-constructed housing such as floating homes, boats, recreation vehicles, campers, motorized homes, light trailers, or tents. It does not include people living in group homes or shelters.

RURV equals the amount of aggregate used to maintain facilities for pre-existing locations for motorized homes and similar units. It equals 0.095 tons per year.

Roads

Every year the Oregon Department of Transportation collects public road mileage data from jurisdictions throughout the state. They total road mileage by surface type and publish the results in the Oregon Mileage Report.

The Oregon Department of Transportation has accurate data on its roads, but statistics from other jurisdictions range widely in quality. Many provide only rough estimates. Others omit or incorrectly classify road mileage. In some cases there are disputes over who has jurisdiction over segments of roads. Having jurisdiction requires a government to pay for maintenance. For these reasons, a reliable time series of road mileage could not be constructed from which to do a regression analysis. We do know, however, that in recent years the quality of the mileage report data has improved.

At the time the model was built, the most recent mileage data available (1993) was used. We added small estimates for unreported mileage. In counties, particularly fast growing ones, private developers build residential roads that are used by the public and are eventually turned over to local governments.

Table Chapter Two -22 is a tabulation of road mileage data from the Oregon Mileage Report. This table excludes BLM, US Forest Service, State forest, State park, and primitive roads. It shows total road mileage rising just 1.6% between 1983 and 1993. During that period the state's population climbed 15.3%. One mile was added for every 511 people. The discrepancy between the two is partly caused by reporting errors, but the extent of this is indeterminable. In spite of the data problems, general patterns do emerge from examining annual road mileage statistics for each county.

Road mileage rises in counties that are growing, but this growth lags population growth by wide margins. That is because land acquisition costs make the process of adding new road mileage too expensive for governments. New mileage, therefore, largely comes about from commercial and residential projects where roads are part of the development of privately owned land. These roads are typically turned over to local governments.

While total mileage changes slowly, major shifts occur road types. As counties grow, they improve existing roads. This can be seen from the data on Table Chapter Two -22. In a 10 year period 765 miles of gravel roads were lost while 1,337 miles of asphalt and oil mat roads were added. This pattern was found to be typical for most years in growing counties. Many of those counties also showed small losses in unimproved road mileage as well.

Table Chapter Two -22

Oregon Road Mileage by Road Surface Type 1983 to 1993
Excluding BLM, USFS, and State Forest and Park Roads

Surface Type	*1983 Road Mileage*	*1993 Road Mileage*	*Change in Road Mileage*	*Percent Change*
Concrete	641	688	+47	+7.3%
Asphalt & Oil Mat	28,946	30,283	+1,337	+4.6%
Gravel	12,970	12,205	(765)	(5.9%)
Unimproved	8,011	8,181	+170	+2.1%
Total Road Mileage	50,568	51,357	+789	+1.6%
State Population	2,635,000	3,035,000	+403,000	+15.3%

Equations (79) and (80) are used to forecast the road mileage of State forest and parks roads. Mileage of these roads is not expected to change over time. The forecast is set to the mileage levels of 1993.

Equation (81) forecasts the mileage of public BLM gravel roads. The forecast for the years 2001 to 2050 is set to half of the 1993 level. Reduced logging activity and budget cuts will cause a decline in gravel road mileage on BLM lands. Asphalt and oil mat roads are unlikely to be significantly affected. Their mileage is forecast in equation (82) which sets it equal to the 1993 level. The same method was used for US Forest Service gravel roads in equation (83), and US Forest Service asphalt and oil mat roads in equation (84).

(79) $SFGRM_{C,T} = SFGRM_{C,T=1993}$

(80) $SFARM_{C,T} = SFARM_{C,T=1993}$

(81) $BLGRM_{C,T} = BLGRM_{C,T=1993} * 0.50$

(82) $BLARM_{C,T} = BLARM_{C,T=1993}$

(83) $USGRM_{C,T} = USGRM_{C,T=1993} * 0.50$

(84) $USARM_{C,T} = USARM_{C,T=1993}$

Where:

$SFGRM_{C,T}$ equals the total linear mileage of Oregon State Forest and State Park gravel roads.

$SFARM_{C,T}$ equals the total linear mileage of Oregon State Forest and State Park roads paved with oil mat or asphalt surfaces.

$BLGRM_{C,T}$ equals the total linear mileage of public BLM gravel roads.

$BLARM_{C,T}$ equals the total linear mileage of public BLM roads paved with oil mat or asphalt surfaces.

$USGRM_{C,T}$ equals the total linear mileage of public US forest Service gravel roads.

$USARM_{C,T}$ equals the total linear mileage of public US forest Service roads paved with oil mat or asphalt surfaces.

State and local unimproved road mileage is calculated in equation (85). Unimproved roads may be graded and surfaced with native material, but they are not paved with gravel, asphalt, oil mat, or concrete. They can be driven on with most motor vehicles. All jurisdictions except BLM, US Forest Service, State

Park, and State Forests are included in the "state and local" category. This category also encompasses our estimates of miscellaneous road mileage that was not reported in the Oregon Mileage Report.

Unimproved roads do not use aggregate, but are calculated in the model because they are a component of the total mileage needed in a county. Historically, unimproved road mileage rarely changes from year-to-year in slow growing counties. It declines in faster growing counties because unimproved roads are upgraded. Although between 1983 and 1993, unimproved road mileage grew, this is thought to be due omissions in the 1983 data.

If the number of households in a county rise by less than one percent, equation (85) forecasts no change in unimproved road mileage. In faster growing counties, the road mileage falls 0.1 percent for every percent above one percent that the county grows.

(85) $SRURM_{C,T} = SLURM_{C,T-1}$ - { if (($HH_{C,T} - HH_{C,T-1}$) / $HH_{C,T-1}$) < 0.01 then 0 else $SLURM_{C,T-1}$ * 0.001 * [($HH_{C,T} - HH_{C,T-1}$) / $HH_{C,T-1}$ - 0.001) / 0.01] }
with { $SLURM_{C,T} - SLURM_{C,T-1}$ } being no less than -2.0 miles.

Where:

$SLURM_{C,T}$ equals the total linear mileage of public state and local roads that are graded or unimproved, but are not surfaced with gravel from outside sources. This category does not include primitive roads.

$HH_{C,T}$. equals the number of households living in a specific county in a given year.

Gravel, asphalt, and oil mat surfaces make up 99% of the improved state and local roads in Oregon. Gravel's share of that is negatively related to urban population density. Figure Chapter Two -26 shows this. Counties with high share of gravel roads also have low urban household densities.

Equation (86) forecasts gravel road mileage for state and local roads. It is based on a regression equation. The dependent variable is the natural logarithm of the ratio of gravel road mileage to gravel, asphalt, and oil mat road mileage. The first independent variable is a dummy variable that equals one for western Oregon counties and zero for eastern Oregon counties. It captures the effect of high rainfall. All else being equal, gravel roads are more expensive to maintain in western Oregon because of its wet climate. The second independent variable is the natural logarithm of the urban household density. It factors in the relationship shown in Figure Chapter Two -26. The R^2 of the regression equation is 0.64. The T-statistics for the coefficients of the two independent variables are -1.4 and -3.8, respectively.

(86) $SLGRM_{C,T} = (SLTRM_{C,T} - SLURM_{C,T} - SLCRM_{C,T}) * e^{\{ -0.5891 - 0.2468 * DWEST_C - 0.238 * [Ln (1 + HHDEN_{C,T} * URB_{C,T})] + CAFAGR_C \}}$

Where:

$SLGRM_{C,T}$ is the mileage of state and local gravel roads in a county at then end of a given year.

$SLTRM_{C,T}$ is the total mileage of state and local roads in a county at then end of a given year. It includes all roads with public access except BLM, US Forest, State forest, State park, and primitive roads.

$SLURM_{C,T}$ equals the total linear mileage of public state and local roads that are graded or unimproved, but are not surfaced with gravel from outside sources. This category does not include primitive roads.

$SLCRM_{C,T}$ is the mileage of state and local concrete roads in a county at then end of a given year

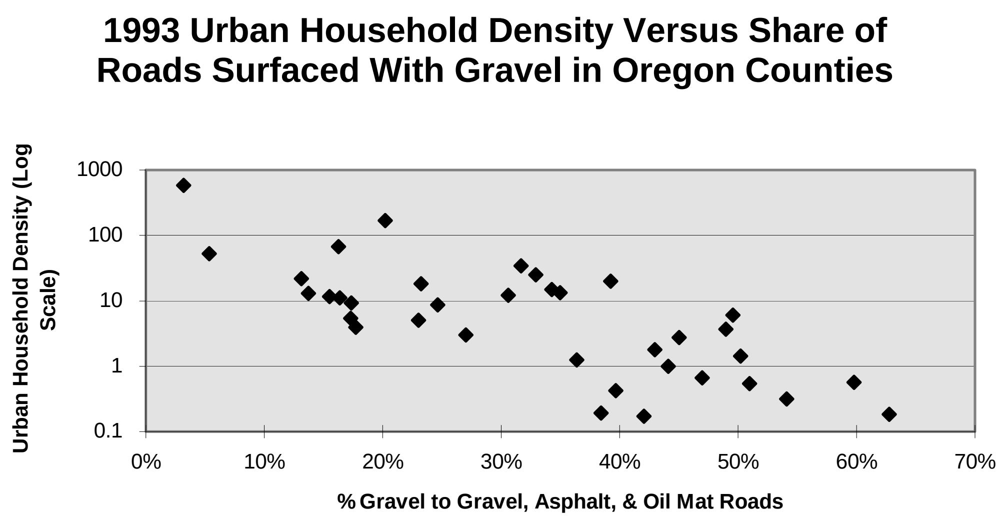
$DWEST_C$ is a dummy variable that equals one for western Oregon counties and zero for eastern Oregon counties.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

$CAFAGR_C$ is a county adjustment factor for gravel road mileage.

Figure Chapter Two -26



The forecast for asphalt and oil mat road mileage is forecast in equation (87). It is an identity where unimproved, concrete, and gravel road mileage is subtracted from the total for state and local roads.

(87) $SLARM_{C,T} = SLTRM_{C,T} - SLURM_{C,T} - SLCRM_{C,T} - SLGRM_{C,T}$

Where:

$SLARM_{C,T}$ is the mileage of state and local roads that have asphalt or oil mat pavements.

$SLTRM_{C,T}$ is the total mileage of state and local roads in a county at then end of a given year. It includes all roads with public access except BLM, US Forest, State forest, State park, and primitive roads.

$SLURM_{C,T}$ equals the total linear mileage of public state and local roads that are graded or unimproved, but are not surfaced with gravel from outside sources. This category does not include primitive roads.

$SLCRM_{C,T}$ is the mileage of state and local concrete roads in a county at then end of a given year.

$SLGRM_{C,T}$ is the mileage of state and local gravel roads in a county at then end of a given year.

Concrete road mileage is forecast using equation (88). It is based on a regression equation using the natural logarithm of concrete road mileage plus one. One is added because some counties have no concrete road mileage and the natural logarithm of zero is incalculable. The independent variables are a dummy variable for counties that have major access to interstate five and 84, and the natural logarithm of the number of households. The regression equation has an R^2 of 0.74. The T-statistics for the coefficients of the independent variables are 3.5 and 8.3, respectively.

(88) $SLCRM_{C,T} = e \{ -6.4112 + 1.0205 * DI584_C + 0.8242 * Ln (HH_{C,T}) + CAFCR_C \} -1$
with $SLCRM_{C,T}$ being no less than zero.

Where:

$SLCRM_{C,T}$ is the mileage of state and local concrete roads in a county at then end of a given year.

e equals approximately 2.718282 and is the base used in natural logarithms.

$DI584_{C}$ is a dummy variable that equals one for any county that has at least ten miles of Interstate 5 or 84 crossing it. For other counties, the variable equals zero.

$HH_{C,T}$ equals the number of households living in a county in a given year.

Ln is the natural logarithm of an expression. It equals the value of the expression in base e (defined below) and is widely used in equations where natural compound growth is a factor.

$CAFCR_{C}$ is the county adjustment factor for concrete road mileage.

Several methods of forecasting road additions were tested in the development of the model. The task was made difficult by the lack of consistent historical data. Equation (89) was chosen because it uses a straightforward method that can be easily modified.

Total state and local road mileage in a county goes up only if there are net additions to housing or construction of non0residential buildings. Road needs are divided between urban and rural. An urban area is defined, as in the rest of the model, as any census block where there is more than one household per ten acres. In those areas 75% of the net additions to single family homes will require new roads at a rate of one mile per 155 households. This is a typical level of density for Oregon. Single family housing includes both site-built and manufactured homes. For rural areas, it is assumed that 25% of the net single family housing additions will need new roads and they will be built at a rate of one mile for every 100 houses.

For multifamily housing, equation (89) does not distinguish between urban and rural areas. Relatively little road mileage is built in Oregon for new multifamily units. The equation assumes that new roads are built for 20% of the net additions of multifamily units and that there is one mile of road for every 500 units. The last part of equation (89) adds one mile of road for every million square feet of non-residential building construction.

(89) $SLTRM_{C,T} = SLTRM_{C,T-1} + URB_{C,T} * 0.75 * \text{if } [(SFLOSS_{C,T} + MANLOSS_{C,T}) > (SFUADD_{C,T} + MANUADD_{C,T}) \text{ then } 0 \text{ else } (SFUADD_{C,T} + MANUADD_{C,T} - SFLOSS_{C,T} - MANLOSS_{C,T})/ 155] + (1 - URB_{C,T}) * 0.25 * \text{if } [(SFLOSS_{C,T} + MANLOSS_{C,T}) > (SFUADD_{C,T} + MANUADD_{C,T}) \text{ then } 0 \text{ else } (SFUADD_{C,T} + MANUADD_{C,T} - SFLOSS_{C,T} - MANLOSS_{C,T})/ 100] + 0.2 * \text{if } [(MFLOSS_{C,T} > MFUADD_{C,T}) \text{ then } 0 \text{ else } (MFUADD_{C,T} - MFLOSS_{C,T}) / 500] + SFBLDG_{C,T} / 1000$

Where:

$SLTRM_{C,T}$ is the total mileage of state and local roads in a county at then end of a given year. It includes all roads with public access except BLM, US Forest, State forest, State park, and primitive roads.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

$SFLOSS_{C,T}$ is the gross number of site-built single family homes that were lost in the county during the year. Losses occur when houses are converted into multifamily units and commercial business places. Losses also happen when homes are torn down (even if a new home replaces the old one), permanently abandoned, or are uninhabitable.

$MANLOSS_{C,T}$ is the gross number of manufactured homes lost in the county during a year. Losses occur when units are moved out of the county, replaced, torn down, permanently abandoned, or become uninhabitable.

$SFUADD_{C,T}$ is the gross number of new site-built single family housing units built in a county during a specific year.

$MANUADD_{C,T}$ is the gross number of manufactured homes put in place in the county for a specific year.

$MFLOSS_{C,T}$ is the gross number of multifamily housing units lost in the county during a year. Losses occur when units are converted into other uses, are torn down, permanently abandoned, or become uninhabitable.

$MFUADD_{C,T}$ is the gross number of new multifamily housing units built in a county during a specific year.

$SFBLDG_{C,T}$ is the total amount of non-residential building construction in a county for a given year in thousands of square feet.

The amount of aggregate used on each mile of road is related to the population density of a county. The more densely populated a county is, the less aggregate it uses per mile of road. The main reason for this is that in highly populated areas there is a greater percentage of residential roads. These experience relatively little wear and, and thus require less aggregate for maintenance as compared to main roads. A detailed discussion on this topic can be found in Special Paper 27.[2]

In the model, aggregate usage rates for state and local roads are divided into three components. The first is aggregate used in the maintenance and repair of existing roads. It is referred to as the normal factor. The second is the growth factor. It measures aggregate use for improving and expanding existing roads so that they can accommodate more traffic. The final component is aggregate used for building new road mileage.

Equation (90) calculates the normal usage factor for state and local gravel roads. The usage rate is much higher in counties with low household densities. This can be seen in Figure Chapter Two -27 where the normal usage factor is plotted against household density. The usage factor for gravel roads is particularly sensitive to density because such roads are much more likely to be used as feeder and arterial routes in rural areas. They are also more likely to carry heavy agricultural and logging truck traffic which cause considerable road damage. In suburban and urban areas, gravel roads are usually only as minor secondary roads which get little attention from road departments.

(90) $AFNSLG_{C,T} = \text{if } (HHDEN_{C,T} < 5) \text{ then } (200 - 60 * HHDEN_{C,T} / 5)$
$\text{if } (5 >= HHDEN_{C,T} < 10) \text{ then } (160 - 40 * (HHDEN_{C,T} - 5) / 5)$
$\text{if } (10 >= HHDEN_{C,T} < 100) \text{ then } (120 - 40 * (HHDEN_{C,T} - 10) / 90)$
$\text{if } (HHDEN_{C,T} >= 100) \text{ then } (80 - 20 * (HHDEN_{C,T} - 100) / 1900)+ 0.183$

Where:

$AFNSLG_{C,T}$ equals the number of tons of aggregate used on every mile of existing state and local gravel road during the year in a county for maintenance, resurfacing, and repairs.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

Equation (91) calculates the growth usage factor for state and local gravel roads. It is assumed that an additional 15 tons per mile are used to expand existing gravel roads for every one percent increase in the number of households.

(91) $AFGSLG_{C,T} = [(HH_{C,T} - HH_{C,T-1}) / HH_{C,T-1}]* 100 * 15$
with $AFGSLG_{C,T}$ having a minimum value of zero.

Where:

[2] Pages 18 - 20, An Economic Analysis of Construction Aggregate Markets and the Results of a Long-Term Forecasting Model for Oregon, Oregon Department of Geology and Mineral Industries, Special Paper 27, 1995.

$AFGSLG_{C,T}$ equals the number of tons of aggregate used on every mile of existing state and local gravel road during the year in a county for expansions to accommodate growth.

$HH_{C,T}$ equals the number of households living in a county in a given year.

The total aggregate usage factor for existing state and local gravel roads is calculated in equation (92). It takes the sum of the normal and growth usage factors and multiplies them times an adjustment factor for a given county. The adjustment factor is based upon a survey of county road departments. It incorporates small differences in the road maintenance and construction practices around the state. In equation (92), the usage factor is increased by 14% to account for slope, embankment, and shoulder work.

$$(92)\ AFESLG_{C,T} = 1.14 * (AFNSLG_{C,T} + AFGSLG_{C,T}) * CARU_C$$

Where:

$AFESLG_{C,T}$ is the total aggregate usage factor in annual tons per mile for existing state and local gravel roads in a given county. It includes aggregate used for repairs, maintenance, improvements, road widening, ice control, slope control, embankments, erosion control, drainage improvements, local access, traffic control, and other features.

$AFNSLG_{C,T}$ equals the number of tons of aggregate used on every mile of existing state and local gravel road during the year in a county for maintenance, resurfacing, and repairs.

$AFGSLG_{C,T}$ equals the number of tons of aggregate used on every mile of existing state and local gravel road during the year in a county for expansions to accommodate growth.

$CARU_C$ is an adjustment factor that may raise or lower the usage rate to match past patterns of aggregate consumption on roads in a given county.

The normal usage factor for state and local, asphalt and oil mat roads is estimated in equation (93). As is seen in Figure Chapter Two -27, the usage rate is somewhat higher in counties with low household densities. Normal usage rate, therefor tend to decline with household density. As counties become highly urbanized counties, however, the greater use of underground utilities lifts usage rates slightly higher.

$$(93)\ AFNSLA_{C,T} = \text{if } (HHDEN_{C,T} < 5) \text{ then } (285 - 30 * HHDEN_{C,T} / 5)$$
$$\text{if } (5 >= HHDEN_{C,T} < 10) \text{ then } (255 - 15 * (HHDEN_{C,T} - 5) / 5)$$
$$\text{if } (10 >= HHDEN_{C,T} < 100) \text{ then } (240 - 40 * (HHDEN_{C,T} - 10) / 90)$$
$$\text{if } (HHDEN_{C,T} >= 100) \text{ then } (200 + 10 * (HHDEN_{C,T} - 100) / 1900)+ 0.183$$

Where:

$AFNSLA_{C,T}$ equals the number of tons of aggregate used on every mile of existing asphalt or oil mat state and local road during the year in a county for maintenance, resurfacing, and repairs.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

Equation (94) calculates the growth usage factor for state and local asphalt or oil mat roads. It is assumed that an additional 20 tons per mile are used to expand existing gravel roads for every one percent increase in the number of households.

$$(94)\ AFGSLA_{C,T} = [(HH_{C,T} - HH_{C,T-1}) / HH_{C,T-1}]* 100 * 25$$
with $AFGSLA_{C,T}$ having a minimum value of zero.

Where:

$AFGSLA_{C,T}$ equals the number of tons of aggregate used on every mile of existing state and local asphalt or oil mat road during the year in a county for expansions to accommodate growth.

$HH_{C,T}$ equals the number of households living in a county in a given year.

Equation (95) is where the model computes the total aggregate usage factor for existing state and local asphalt or oil mat roads. It is an identity that takes the same form as equation (92).

$$(95)\ AFESLA_{C,T} = 1.14 * (AFNSLA_{C,T} + AFGSLA_{C,T}) * CARU_C$$

Where:

$AFESLA_{C,T}$ is the total aggregate usage factor in annual tons per mile for existing state and local asphalt or oil mat roads in a given county. It includes aggregate used for repairs, maintenance, improvements, road widening, ice control, slope control, embankments, erosion control, drainage improvements, local access, traffic control, and other features.

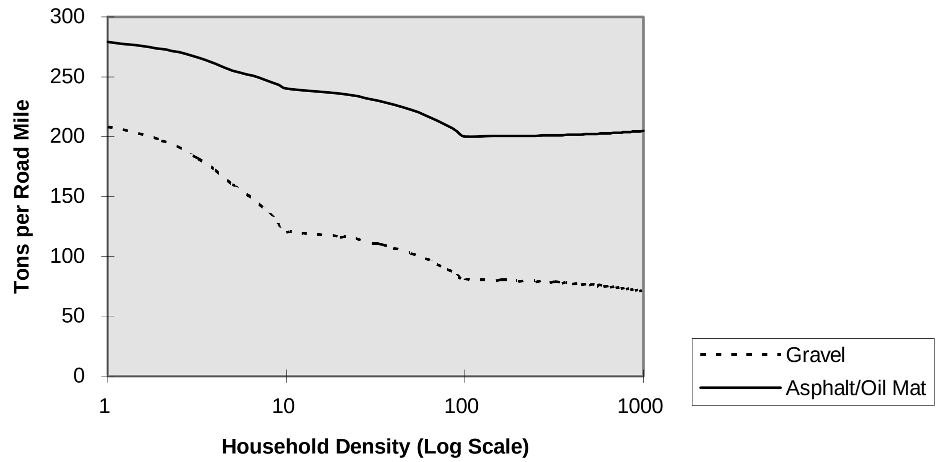
$AFNSLA_{C,T}$ equals the number of tons of aggregate used on every mile of existing asphalt or oil mat state and local road during the year in a county for maintenance, resurfacing, and repairs.

$AFGSLA_{C,T}$ equals the number of tons of aggregate used on every mile of existing state and local asphalt or oil mat road during the year in a county for expansions to accommodate growth.

$CARU_C$ is an adjustment factor that may raise or lower the usage rate to match past patterns of aggregate consumption on roads in a given county.

Figure Chapter Two -27

Normal Aggregate Usage Factors for Gravel and Asphalt Roads Versus County Household Densities



The growth usage factor for state and local concrete roads is calculated in equation (96). Fifteen tons per mile is consumed for every one percent increase in the number of households in a county. Concrete roads tend to be wide, but very durable. The normal usage factor is estimated to be 120 tons per mile per year. Another 0.183 tons is added to account for aggregate used in snow and ice control. Normal usage rates vary little between counties, so there is no separate equation for it in the model.

(96) $AFGSLC_{C,T} = [(HH_{C,T} - HH_{C,T-1}) / HH_{C,T-1}]* 100 * 15$
with $AFGSLC_{C,T}$ having a minimum value of zero.

Where:

$AFGSLC_{C,T}$ equals the number of tons of aggregate used on every mile of existing state and local concrete road during the year in a county for expansions to accommodate growth.

$HH_{C,T}$ equals the number of households living in a county in a given year.

Total aggregate usage for existing state and local concrete roads is estimated in equation (97).

(97) $AFESLC_{C,T} = 1.14 * (AFNSLC + AFGSLC_{C,T}) * CARU_C$

Where:

$AFESLC_{C,T}$ is the total aggregate usage factor in annual tons per mile for existing state and local concrete roads in a given county. It includes aggregate used for repairs, maintenance, improvements, road widening, ice control, slope control, embankments, erosion control, drainage improvements, local access, traffic control, and other features.

AFNSLC equals the number of tons of aggregate used on every mile of existing concrete state and local road during the year for maintenance, resurfacing, and repairs. It is a constant and it equals 120.183 tons per mile.

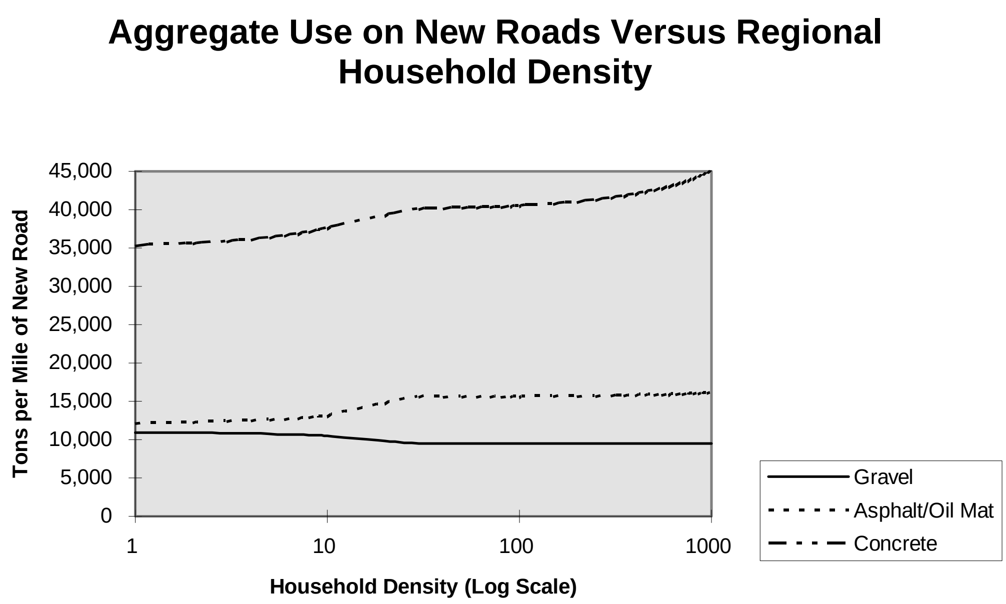
$AFGSLC_{C,T}$ equals the number of tons of aggregate used on every mile of existing state and local concrete road during the year in a county for expansions to accommodate growth.

$CARU_C$ is an adjustment factor that may raise or lower the usage rate to match past patterns of aggregate consumption on roads in a given county.

The amount of aggregate used on newly constructed roads depends on the type of pavement, road width, local construction standards, and anticipate traffic levels. Generally, the more densely populated a community is, the more aggregate it will use in building a mile of asphalt, oil mat, or concrete road. For gravel roads the opposite is true because they are relegated to only minor secondary uses in highly populated counties.

Figure Chapter Two -28 is a graph comparing aggregate use per mile of new road to household density for three different surface types. The graph was drawn using equations 97, 98, and 99.

Figure Chapter Two -28



Equation (97) calculates the number of tons of aggregate used per mile of new state and local gravel given the household density of a county.

$$(97)\ AFNEWSLG_{C,T} = \text{if } (HHDEN_{C,T} < 10) \text{ then } (11000 - 500 * HHDEN_{C,T} / 10)$$
$$\text{if } (10 >= HHDEN_{C,T} < 25) \text{ then } (10500 - 1000 * (HHDEN_{C,T} - 10) / 15)$$
$$\text{if } (HHDEN_{C,T} >= 25) \text{ then } (9500 + 1000 * (HHDEN_{C,T} - 25) / 1975)$$

with $AFNEWSLG_{C,T}$ having a minimum value of zero.

Where:

$AFNEWSLG_{C,T}$ equals the number of tons of aggregate used on every mile of new gravel state and local road.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

The amount of aggregate used on each new mile of state and local asphalt or oil mat road is estimated in equation (98).

$$(98)\ AFNEWSLA_{C,T} = \text{if } (HHDEN_{C,T} < 10) \text{ then } (12000 - 1000 * HHDEN_{C,T} / 10)$$
$$\text{if } (10 >= HHDEN_{C,T} < 25) \text{ then } (13000 - 25000 * (HHDEN_{C,T} - 10) / 15)$$
$$\text{if } (HHDEN_{C,T} >= 25) \text{ then } (15500 + 1000 * (HHDEN_{C,T} - 25) / 1975)$$

with $AFNEWSLA_{C,T}$ having a minimum value of zero.

Where:

$AFNEWSLA_{C,T}$ equals the number of tons of aggregate used on every mile of new asphalt or oil mat state and local road.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

The amount of aggregate used on each new mile of state and local concrete road is estimated in equation (99).

$$(99)\ AFNEWSLC_{C,T} = \text{if } (HHDEN_{C,T} < 10) \text{ then } (12000 - 1000 * HHDEN_{C,T} / 10)$$
$$\text{if } (10 >= HHDEN_{C,T} < 25) \text{ then } (13000 - 25000 * (HHDEN_{C,T} - 10) / 15)$$
$$\text{if } (HHDEN_{C,T} >= 25) \text{ then } (15500 + 1000 * (HHDEN_{C,T} - 25) / 1975)$$

with $AFNEWSLC_{C,T}$ having a minimum value of zero.

Where:

$AFNEWSLC_{C,T}$ equals the number of tons of aggregate used on every mile of new concrete state and local road.

$HHDEN_{C,T}$ is the household density of a county for a given year. It equals the number of households per square mile of land.

Private logging activity in Oregon is a major market for aggregate. Most of it is used on private logging roads, but some is also used to create secure places for storing equipment, supplies, and lumber. Large industrial forest products companies use more aggregate than small, private timber companies which tend to operate mostly in the dry Summer months. There are also regional differences in aggregate use for logging. Considerably more rock is put onto roads in the Coastal Mountain Range where rainfall is high than on roads in dry areas of central Oregon. . These differences are captured in equation (100).

(100) $ALOGR_{C,T} = PTI_{C,T} * AFPT_C * TECH_T + PTS_{C,T} * 0.5 * AFPT_C * TECH_T$

Where:

$ALOGR_{C,T}$ equals the total use of aggregate by private logging companies in a county for a given year.

$PTI_{C,T}$ is the size of the industrial timber harvest in million board feet.

$AFPT_C$ is the usage rate of aggregate in tons per million board feet of industrial timber harvest for a given county.

$TECH_T$ is the statewide technology factor for the forecast year.

$PTS_{C,T}$ is the size of the timber harvest by small private loggers.

Equation (101) calculates the amount of aggregate used on BLM, US Forest Service, State Forestry, and State park roads.

(101) $AFORR_{C,T} = TECH_T * 55 * SFGRM_{C,T} + TECH_T * 40 * (BLGRM_{C,T} + USGRM_{C,T}) + TECH_T * 70 * SFARM_{C,T} + TECH_T * (1 + DWEST_C) * 30 * (BLARM_{C,T} + USARM_{C,T})$

Where:

$AFORR_{C,T}$ equals the total use of aggregate on BLM, US Forest Service, State Forestry, and State park roads in a county for a given year.

$TECH_T$ is the statewide technology factor for the forecast year.

$SFGRM_{C,T}$ equals the total linear mileage of Oregon State Forest and State Park gravel roads.

$BLGRM_{C,T}$ equals the total linear mileage of public BLM gravel roads.

$USGRM_{C,T}$ equals the total linear mileage of public US forest Service gravel roads.

$SFARM_{C,T}$ equals the total linear mileage of Oregon State Forest and State Park roads paved with oil mat or asphalt surfaces.

$DWEST_C$ is a dummy variable that equals one for western Oregon counties and zero for eastern Oregon counties.

$BLARM_{C,T}$ equals the total linear mileage of public BLM roads paved with oil mat or asphalt surfaces.

$USARM_{C,T}$ equals the total linear mileage of public US forest Service roads paved with oil mat or asphalt surfaces.

Aggregate used to improve, maintain, and repair existing state and local gravel roads is calculated in the identity shown below as equation (102).

(102) $AMGR_{C,T} = AFESLG_{C,T} * SLGRM_{C,T}$

Where:

$AMGR_{C,T}$ equals the total number of tons of aggregate used to improve, maintain, and repair existing state and local gravel roads.

$AFESLG_{C,T}$ is the total aggregate usage factor in annual tons per mile for existing state and local gravel roads in a given county. It includes aggregate used for repairs, maintenance, improvements, road widening, ice control, slope control, embankments, erosion control, drainage improvements, local access, traffic control, and other features.

$SLGRM_{C,T}$ is the mileage of state and local gravel roads in a county at then end of a given year.

Aggregate used to improve, maintain, and repair existing state and local asphalt or oil mat roads is calculated in the identity shown below as equation (103).

(103) $AMAR_{C,T} = AFESLA_{C,T} * SLARM_{C,T}$

Where:

$AMAR_{C,T}$ equals the total number of tons of aggregate used to improve, maintain, and repair existing state and local asphalt or oil mat roads.

$AFESLA_{C,T}$ is the total aggregate usage factor in annual tons per mile for existing state and local asphalt or oil mat roads in a given county. It includes aggregate used for repairs, maintenance, improvements, road widening, ice control, slope control, embankments, erosion control, drainage improvements, local access, traffic control, and other features.

$SLARM_{C,T}$ is the mileage of state and local asphalt or oil mat roads in a county at then end of a given year.

Aggregate used to improve, maintain, and repair existing state and local concrete roads is calculated in the identity shown below as equation (104).

(104) $AMCR_{C,T} = AFESLC_{C,T} * SLCRM_{C,T}$

Where:

$AMCR_{C,T}$ equals the total number of tons of aggregate used to improve, maintain, and repair existing state and local concrete roads.

$AFESLC_{C,T}$ is the total aggregate usage factor in annual tons per mile for existing state and local concrete roads in a given county. It includes aggregate used for repairs, maintenance, improvements, road widening, ice control, slope control, embankments, erosion control, drainage improvements, local access, traffic control, and other features.

$SLCRM_{C,T}$ is the mileage of state and local concrete roads in a county at then end of a given year

Aggregate used for building new roads is calculated in equations 105, 106, and 107. The aggregate consumed for slopes, embankments, erosion control, and other indirect effects of new road construction is estimated in equation 108.

(105) $ANGR_{C,T} = AFNEWSLG_{C,T} * (SLGRM_{C,T} - SLGRM_{C,T-1})$

Where:

$ANGR_{C,T}$ equals the total number of tons of aggregate used directly on new state and local gravel roads.

$AFNEWSLG_{C,T}$ equals the number of tons of aggregate used on every mile of new gravel state and local road.

$SLGRM_{C,T}$ is the mileage of state and local gravel roads in a county at then end of a given year.

(106) $ANAR_{C,T} = AFNEWSLG_{C,T} * (SLGRM_{C,T} - SLGRM_{C,T-1})$

Where:

$ANAR_{C,T}$ equals the total number of tons of aggregate used directly on new state and local asphalt and oil mat roads.

$AFNEWSLA_{C,T}$ equals the number of tons of aggregate used on every mile of new asphalt and oil mat state and local road.

$SLARM_{C,T}$ is the mileage of state and local asphalt and oil mat roads in a county at then end of a given year.

(107) $ANCR_{C,T} = AFNEWSLC_{C,T} * (SLCRM_{C,T} - SLCRM_{C,T-1})$

Where:

$ANCR_{C,T}$ equals the total number of tons of aggregate used directly on new state and local concrete roads.

$AFNEWSLC_{C,T}$ equals the number of tons of aggregate used on every mile of new concrete state and local road.

$SLCRM_{C,T}$ is the mileage of state and local concrete roads in a county at then end of a given year.

(108) $ASLOPE_{C,T} = 0.25 * (ANGR_{C,T} + ANAR_{C,T} + ANCR_{C,T})$

Where:

$ASLOPE_{C,T}$ equals the total number of tons of aggregate used for slopes, embankments, staging areas, erosion control, environmental mitigation, and other activities during new road construction.

$ANGR_{C,T}$ equals the total number of tons of aggregate used directly on new state and local gravel roads.

$ANAR_{C,T}$ equals the total number of tons of aggregate used directly on new state and local asphalt and oil mat roads.

$ANCR_{C,T}$ equals the total number of tons of aggregate used directly on new state and local concrete roads.

Railroad Track

Equation (109) forecasts the consumption of aggregate used as ballast in maintaining railroad tracks.

(109) $ARRT_{C,T} = TECH_T * RRM_{C,T} * AFRRM_C + TECH_T * RRS_{C,T} * AFRRS_C + TECH_T * RRP_{C,T} * AFRRP_C$

Where:

$ARRT_{C,T}$ equals the tons of aggregate used each year for maintaining railroad tracks. It does not include aggregate consumed for railroad crossings, sidings, stations, or yards.

$TECH_T$ is the statewide technology factor for the forecast year.

$RRM_{C,T}$ equals the number of miles of main line railroad track in a county.

$AFRRM_C$ is a constant. It is the number of tons per year used to maintain a mile of main line railroad track in a given county.

$RRS_{C,T}$ equals the number of miles of short line railroad track in a county.

$AFRRS_C$ is a constant. It is the number of tons per year used to maintain a mile of short line railroad track in a given county.

$RRP_{C,T}$ equals the number of miles of passing track for main line routes in a county.

$AFRRP_C$ is a constant. It is the number of tons per year used to maintain a mile of passing track along side a main line route in a given county.

Farms

Farms, ranches, and other agricultural businesses use of aggregate. No data is collected on this consumption, but it is known to be substantial. Major uses in agriculture include container nurseries, roads on ranches, irrigation systems, and areas for parking heavy equipment and vehicles.

There is no system in the model to drive a forecast of aggregate consumption in agriculture. Instead, it is assumed that total consumption will equal estimates made for 1994 less adjustments for substitution and technology. The 1994 estimates are based on the size and types of farms in each county. These estimates appear in Table Chapter Two -23. This data is used in equation (110).

(110) $AFARM_{C,T} = TECH_{T} * FARM_{C}$

Where:

$AFARM_{C,T}$ is the amount of aggregate used in a year on farms, ranches, and other agricultural businesses in a given county.

$TECH_{T}$ is the statewide technology factor for the forecast year.

$FARM_{C}$ is the 1994 estimate of aggregate use in agriculture for a given county.

Table Chapter Two -23

Aggregate Consumption by Farms, Ranches, and Other Agricultural Business in 1994

County	*Tons*
Baker	39,847
Benton	10,035
Clackamas	31,916
Clatsop	2,321
Columbia	4,824
Coos	14,354
Crook	32,693
Curry	4,696
Deschutes	9,105
Douglas	26,713
Gilliam	24,293
Grant	35,375
Harney	51,279
Hood River	7,898
Jackson	20,998
Jefferson	24,556
Josephine	3,785
Klamath	44,251
Lake	34,726
Lane	20,385
Lincoln	2,730
Linn	34,679
Malheur	73,510
Marion	42,794
Morrow	41,248
Multnomah	10,551
Polk	16,225
Sherman	18,566
Tillamook	6,326
Umatilla	77,453
Union	25,902
Wallowa	30,452
Wasco	42,868
Washington	21,867
Wheeler	21,046
Yamhill	19,833
State	930,101

Repair, Maintenance, Improvements, and Other

Large amounts of aggregate are used to repair, maintain, and improve existing buildings and infrastructure. Most of this activity is not included in the forecasts of construction by type in the model. In addition, some new building construction is overlooked in the data. For those reasons, we must estimate the amount of aggregate needed for repairs, maintenance, and improvements and for new construction not captured elsewhere in the data used in the model. Examples of aggregate consumption in this category are building renovations, repairs to sidewalks, hook-ups of existing buildings to sewer mains, building additions, conversions of houses into businesses, swimming pools, and repaving parking lots.

Equation (111) forecasts the amount of aggregate for repairs, maintenance, and improvements to existing non-residential buildings and construction for non-residential buildings not elsewhere classified in the model. With little historical data to work with, the equation was constructed using assumptions on how this category is related to other factors in the model. Before doing this, however, we knew approximately how much aggregate was used in 1993 in all types of repairs, maintenance, improvements, and other forms of construction. This was accomplished by forecasting aggregate consumption in known categories, such as new schools, for the year 1993. We then subtracted aggregate use for the known categories from total actual consumption in Oregon (which was determined by a survey).

In equation (111) we estimate aggregate use for repairs, maintenance, improvements, and other work on non-residential buildings. Part of the estimate equals 25% of the aggregate used in new buildings. The tie-in to new building construction is done because market conditions that stimulate such activity is correlated with the demand for additions, improvements, and renovations in older buildings. The second part of the estimate is related to population after adjustments for income levels and population densities. The population factor is used because maintenance and repair work for non-residential buildings goes on independently of new construction activity. Since there is no stock data on non-residential buildings in the model, population is used as a proxy.

The relationship between population density and per capita aggregate consumption is not one-to-one.[3] Figure Chapter Two -29 is a plot of 1990 per capita consumption for each of the 50 states versus the independent variable of population density. The fitted values between the natural logarithms of the two variables is plotted as a solid line. It is based on a regression equation whose R^2 is 0.51. The T-statistic of the independent variable's coefficient is +7.1.

The results of this regression are factored into equation (111). It uses the county population density in the regression equation. The result is divided by 11.411. Doing so indexes it to a value of one for the state of Oregon. A county with a low population density may have an index value of two. In that case its per capita consumption level will be twice as high as the state average. The result is further indexed in proportion to the state average of real personal income.

$$(111)\ ARMINR_{C,T} = (0.25 * [AFARM_{CT} + ANRBLDG_{CT} + 0.95 * APOW_{CT} + 0.10 * AFPT_{CT}) + (PIHH_{CT} / 39350 * POP_{CT} * e^{\{ 3.209925 - 0.22959 * Ln (POPDEN_{CT}) \}} / 11.411) * TECH_{T}$$

Where:

$ARMINR_{C,T}$ equals the amount of aggregate for the repair, maintenance, and improvements to existing non-residential buildings and construction for non-residential buildings not elsewhere classified in the model.

$AFARM_{C,T}$ is the amount of aggregate used in a year on farms, ranches, and other agricultural businesses in a given county.

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[3] Page 15, An Economic Analysis of Construction Aggregate Markets and the Results of a Long-Term Forecasting Model for Oregon, Oregon Department of Geology and Mineral Industries, Special Paper 27, 1995.

$ANRBLDG_{CT}$ aggregate used for new construction of non-residential buildings calculated elsewhere in the model. Include airport, detention center, health care, lodging, manufacturing, municipal, office, public assembly, retail, school, warehouse, parking garage, and miscellaneous buildings.

$APOW_{CT}$ is the amount of aggregate used in the construction of power and heat facilities in a county for a specific year.

$AFPT_{C}$ is the usage rate of aggregate in tons per million board feet of industrial timber harvest for a given county.

$PIHH_{C,T}$ equals personal income per household, in 1987 dollars, for a county in a specified year.

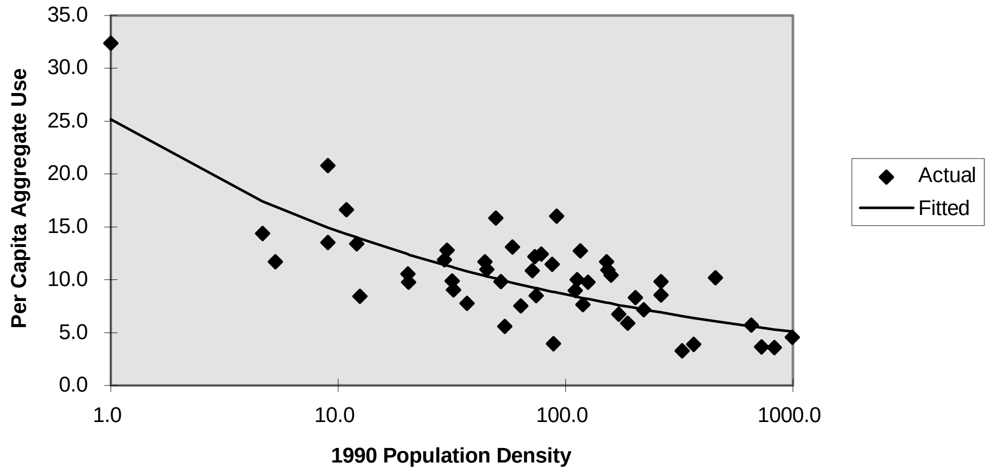
$POP_{C,T}$ is the total population of a county for the specified year.

$POPDEN_{C,T}$ is the population density for a county in a given year. It is in terms of people per square mile of land.

$TECH_{T}$ is the statewide technology factor for the forecast year.

Figure Chapter Two -29

Relationship Between 1990 Population Density and Per Capita Aggregate Consumption by State



Equation (112) is used to forecast aggregate consumed in repairs, maintenance, and improvements to existing residential buildings and properties. Data for this end-use does not exist and the equation had to be constructed based on activities in housing. It is assumed that , in a typical Oregon county, 0.50 cubic years of aggregate are used each year for every occupied single family home. Consumption is 0.40 tons for occupied manufactured homes and 0.25 tons for multifamily units. The quantities used for single family homes are higher or lower depending upon the household income of the county. Improvements to existing residential buildings and properties are tied to activity in new residential construction. This is accounted for in the equation by adding in an incremental amount that equals 10 percent of the aggregate used in new residential construction.

(112) $ARMIR_{C,T} = \{ [(PIHH_{CT} / 39350) * (0.5 * SFU_{CT} + 0.4 * MANU_{CT}) + (0.25 * MFU_{CT})] * (HU_{CT} - HUEMP_{CT}) / HU_{CT} * 1.425 + 0.1 * AHOU_{CT} \} * TECH_{T}$

Where:

$ARMIR_{C,T}$ is the amount of aggregate for the repair, maintenance, and improvements to existing residential buildings and properties.

$PIHH_{C,T}$ equals personal income per household, in 1987 dollars, for a county in a specified year.

$SFU_{C,T}$ equals the number of single family site built homes that exist in a county at year end. It includes occupied, vacant, and seasonal units.

$MANU_{C,T}$ equals the number of manufactured homes in a county at year end. This does not include motorized homes or light trailers. This category encompasses occupied, vacant, and seasonal units.

$MFU_{C,T}$ equals the number of multifamily housing units that exist in a county at year end. A multifamily unit is part of a larger building. A single building has at least two units in it. This category encompasses occupied, vacant, and seasonal units.

$HUEMPT_{C,T}$ equals the number of vacant units of single family homes, manufactured homes, and multifamily homes.

$HU_{C,T}$ equals the total number of housing units in a county for the end of a given year. It includes all occupied, seasonal, and vacant housing. It also include household units that are homeless or live non-constructed forms of housing such as boats and campers.

$AHOU_{CT}$ is the sum of aggregate consumption for putting in new single family, multifamily, other forms of housing, and conversions a given county.

$TECH_{T}$ is the statewide technology factor for the forecast year.

Aggregate used for repairs, maintenance, and improvements to existing infrastructure and to build new infrastructure not elsewhere classified in the model is calculated in equation (113). As with the previous two equations, this equation was constructed based upon assumptions for a category where no data is collected. Much of the aggregate used in infrastructure maintenance and repair work goes into utility lines, waste water lines, sidewalks, curbs, and other features which parallel roads. The equation assumes that 10 tons are used each year per mile of paved road and two tons for every mile of gravel road. An amount equal to ten percent of identified new infrastructure spending is assumed to be used for this category. In addition, another ton per household, adjusted for income and population density, is included.

(113) $ARMII_{C,T} = [\ 10 * (\ SLARM_{CT} + SLCRM_{CT}\ ) + 2 * SLGRM_{CT} + 0.10 * (\ 0.05 * APOW_{CT} + AINFRA_{CT}\ ) + HH_{CT} * (\ PIHH_{CT} / 39350 * POP_{CT} * e^{\{ 3.209925 - 0.22959 * Ln (\ POPDEN_{CT}\ ) \}} / 11.411\ ) * TECH_{T}$

Where:

$ARMII_{C,T}$ equals the amount of aggregate for the repair, maintenance, and improvements to existing infrastructure and infrastructure not elsewhere classified in the model. Repairs, maintenance and improvements to public roads is not included in this category.

$SLARM_{C,T}$ is the mileage of state and local roads that have asphalt or oil mat pavements.

$SLCRM_{C,T}$ is the mileage of state and local concrete roads in a county at then end of a given year.

$SLGRM_{C,T}$ is the mileage of state and local gravel roads in a county at then end of a given year.

$APOW_{CT}$ is the amount of aggregate used in the construction of power and heat facilities in a county for a specific year.

$AINFRA_{CT}$ is the amount of aggregate used for infrastructure construction calculated in the model. It includes new roads, airport runways, bridges, dams, reservoirs, miscellaneous non-building construction, river and marine projects, sewer and water projects, sidewalks and parking not elsewhere classified.

$HH_{C,T}$. equals the number of households living in a specific county in a given year.

$PIHH_{C,T}$ equals personal income per household, in 1987 dollars, for a county in a specified year.

$POP_{C,T}$ is the total population of a county for the specified year.

$POPDEN_{C,T}$ is the population density for a county in a given year. It is in terms of people per square mile of land.

$TECH_{T}$ is the statewide technology factor for the forecast year.

Equation (114) estimates aggregate consumption for miscellaneous uses. This includes landscaping, trails, filtering media, golf courses, environmental mitigation work, landfills, retaining walls, fountains, cemeteries, light rail stops, and outdoor recreational facilities.

The equation is based on the assumption that five percent of the aggregate consumed in Oregon during 1993 was used in this category. Nationally, other uses amount to five percent of consumption. According to a survey by DOGAMI, 1993 aggregate consumption in Oregon was 53,273,017 tons. Other uses in Oregon, therefore were about 2,663,651 tons. We further assumed that 75 percent of that consumption was done to satisfy the needs of existing residents and that 25 percent was used to accommodate population growth. This is the approximate breakdown between the two groups in other categories of consumption. Based on the assumptions outlines above, 0.66 tons of aggregate are used for each resident and another 11.22 tons are used for each new resident.

(114) $AOTHER_{C,T} = \{ 0.66 * POP_{CT} + [\text{if} (POP_{CT} > POP_{CT-1}) \text{ then } 11.22 * (POP_{CT} - POP_{CT-1}) \text{ else } 0] \} * TECH_{T}$

Where:

$AOTHER_{C,T}$ is the total amount of aggregate used for non-construction projects and miscellaneous construction work not elsewhere classified in the model.

$POP_{C,T}$ is the total population of a county for the specified year.

$TECH_{T}$ is the statewide technology factor for the forecast year.

Power and Heat

Power and heat construction includes natural gas pipelines, power plants, electric substations, transmission lines, storage tanks, and steam power facilities. Power and heat work done as part of other projects, such as the construction of a steel mill or school, are not included in this category. Historically, the power and heat category has been a very small market for aggregate in Oregon. In some rural counties, however, this end-use has been significant.

The pattern of construction of power and heat projects is weakly correlated with area and population. Area is related to this category because the length of power and gas lines tends to be greater in larger counties. Places with high population, on the other hand, are more likely to have electric substations. When constructed, these use large amounts of crushed rock.

Neither area nor population produced a particularly reliable equation that fit all the counties. Since it is a minor end-use, a simple identity equation was constructed.

Equation (115) calculates the amount of construction for power and heat projects in a county. It assumes that it is a function of land area and the number of households. The equation simply takes an average of the area and household factors for the state over the 16 year historical period from 1978 to 1993. An adjustment factor accounts for the historical difference between using the averages and the actual historical data for the county.

(115) $POWC_{C,T} = (10/9) * [(1/2) * (0.549 * AREA_C + 0.0505 * HH_{C,T})] + CAFPOW_C$

(116) $APOW_{C,T} = POWC_{C,T} * (AFPOW_C + CPFPOW_C) * TECH_T$

Where:

$POWC_{C,T}$ equals the amount of money spent on the construction of heat and power infrastructure in a county for a given year. It is measured in thousands of 1987 dollars.

$AREA_C$ equals the land area of a county in square miles.

$HH_{C,T}$. equals the number of households living in a specific county in a given year.

$CAFPOW_C$ is the factor for power and heat construction that adjusts for the difference between the fitted and actual historical values for a given county.

$APOW_{CT}$ is the amount of aggregate used in the construction of power and heat facilities in a county for a specific year.

$AFPOW_C$ is the amount of aggregate used per thousand 1987 dollars spent on heat and power construction projects. For western Oregon, it equals 2.60 tons. For projects in eastern Oregon, it is 2.20 tons.

$CPFPOW_C$ is the amount of aggregate, in the forms of precast, pre stressed, and masonry concrete products, used per thousand 1987 dollars spent on heat and power construction projects. It equals 0.084 tons.

$TECH_T$ is the statewide technology factor for the forecast year.

Airport Runways

Airport runways include runways and taxiways at public and private airports. From 1978 to 1993, runway construction took place in all but one county in Oregon. Most of the activity, however, occurred at commercial airports.

The amount of construction for runways is calculated in equation (117). Construction is measured in thousands of 1987 dollars. The equation combines the results of two regression equations. One calculates runway construction spending for counties with commercial airports. The other calculates spending for those without commercial airports.

(117) $RWC_{C,T}$ = (10/9) * if $DCOMAIR_C$ = 0 then { 0.000569 * $HH_{C,T}$ + 0.00687 * [if ($HH_{C,T}$ > $HH_{C,T-1}$) then ($HH_{C,T}$ - $HH_{C,T-1}$) else 0] } else { 0.002276 * $HH_{C,T}$ + 0.00687 * [if ($HH_{C,T}$ > $HH_{C,T-1}$) then ($HH_{C,T}$ - $HH_{C,T-1}$) else 0]

with $RWC_{C,T}$ for Wheeler County equal to zero.

(118) $ARWC_{C,T}$ = $RWC_{C,T}$ * $AFRW_C$ * $TECH_T$

Where:

$RWC_{C,T}$ equals the amount of money spent on the construction of airport runways and taxiways in a county for a given year. It is measured in thousands of 1987 dollars.

$DCOMAIR_C$ equals one if a county has a commercial airport and zero if it does not have a commercial airport.

$HH_{C,T}$. equals the number of households living in a specific county in a given year.

$ARWC_{C,T}$ is the amount of aggregate used in the construction of runways and taxiways in a county for a specific year.

$AFRW_C$ is the amount of aggregate used per thousand 1987 dollars spent on runways and taxiways construction. For western Oregon, it equals 14.30 tons. For projects in eastern Oregon, it is 12.10 tons.

$TECH_T$ is the statewide technology factor for the forecast year.

Miscellaneous Sidewalks and Parking

Sidewalk and parking lot construction is a big market for aggregate. In the model, much of this market is hidden in the construction statistics of other categories. For instance, when a new retail outlet is built, the aggregate usage factors include material needed for parking, sidewalks, and curbs. Repaving old sidewalks and parking lots is covered repair and maintenance categories. The miscellaneous sidewalks and parking category, therefore, covers a small subsection of all the activity in those areas of construction. The category includes only projects measured by FW Dodge as sidewalk and parking lot construction contracts. It averages about four million dollars a year.

Equation (119) calculates miscellaneous sidewalks and parking construction not elsewhere included in the model.

(119) $SWPC_{C,T} = (10/9) * [- 17.97* (0.004057 * HH_{C,T}. * URB_{C,T} + 0.077546 * (HH_{C,T} - HH_{C,T-1}) * URB_{C,T}] + CAFSWP_C$

with $SWPC_{C,T}$ having a minimum value of 0.1.

(120) $ASWP_{C,T} = SWPC_{C,T} * (AFSWP_C + CPFSWP_C) * TECH_T$

Where:

$SWPC_{C,T}$ equals the amount of money spent on the construction of sidewalks and surface parking projects measured by FW Dodge recorded in thousands of 1987 dollars.

$HH_{C,T}$. equals the number of households living in a specific county in a given year.

$URB_{C,T}$ is the ratio of residents living in census blocks with more than one household per ten acres over the total population. It is a rough measure of the proportion of people living in towns, cities, and suburban areas for a specified year.

$ASWP_{C\ T}$ is the amount of aggregate used in sidewalks and surface parking projects.

$AFSWP_C$ is the amount of aggregate used directly per thousand 1987 dollars worth of construction on sidewalks and parking lots. For western Oregon it is set to 20.67 tons. It is 17.49 tons in the rest of the state.

$CPFPOW_C$ is the amount of aggregate, in the forms of precast, pre stressed, and masonry concrete products, used per thousand 1987 dollars spent on sidewalk and parking lot projects. It equals 0.214 tons.

$TECH_T$ is the statewide technology factor for the forecast year.

Chapter Three
Running Alternative Versions of the Model

Introduction

You can modify the aggregate models so that they produce different forecasts. This chapter explains two basic methods for doing this.

The first method generates a new forecast by making changes to the exogenous data. These forecasts are called scenarios. They are sometimes called “what if” experiments. A scenario shows what a forecast would be if the exogenous data were different. For example, we might run a scenario that shows what aggregate consumption would be in a county if its population grows at a faster rate than we initially forecast.

In the second method we overhaul the model for one county so that it forecasts consumption for a different region. We keep the same model structure, but we change much of the data and coefficients used in the equations. For instance, a model for Marion County Oregon can be modified so that it forecasts aggregate consumption in Orange County California.

Running Scenarios

Exogenous data for population, income, and seasonal housing are easily changed in the county aggregate models. This exogenous data drive the forecasts for housing, constructions, road mileage, and aggregate consumption. By typing in new exogenous data for one or more of the years between 2001 and 2050, the forecasts produced by the models will change.

Below is a list of the exogenous data that can be readily changed in a model. To make a change, type in a new forecast for one or more of the exogenous variables. The appropriate line number where the exogenous variable is in the model is shown.

1. **Seasonal housing** is forecast using a variable on line four. The variable equals the ratio of seasonal housing units to total households in the state. It is an exogenous variable and is on line three in the model.
2. **County demographic data** consists of five related series. You should not change one series without making suitable adjustments to the others. For instance, if the forecast for the population over 64 years old is raised, a similar increase must be made to the total population forecast. A smaller increase in the number of households should also be made.
    - Total population (line 58).
    - Population in the 0 - 17 age group (line 59).
    - Population in the 18 - 64 age group (line 60).
    - Population over 64 years old (line 61).
    - Total number of households (line 62). Any change in this variable should be reflected in the total number of households in the state (line three) which is used to drive the forecast for seasonal housing.
3. **Personal income** can be changed on line 63. Here, the personal income per capita, in 1987 dollars, is used as an exogenous variable.

Changing the Seasonal Housing Variable

Changing the seasonal housing variable is simple. The variable on line four is a ratio for the whole state. It is the number of seasonal housing units divided by all units that are occupied year-round. Seasonal housing consists mostly of vacation homes, recreational cabins, and migrant labor housing. The number of occupied units equals the number of households in the state. This ratio between the two changes slowly.

Only modest year-to-year changes should be made to the ratio. This exogenous variable reflects gradual shifts in the make-up of the state's housing stock. A sudden change would be unrealistic.

In the model, the forecast shows the ratio rising slowly over time. Over the past 20 years, it has grown steadily as more people have been willing and able to build new vacation homes around the state.

If the ratio is raised, the number of seasonal units in the housing stock goes up. This causes more construction and aggregate use for new housing. Both multifamily and single family construction benefit. Small increases occur in road, infrastructure, non-residential construction. Total aggregate consumption rises.

Changing the Demographic Variables

The demographic data in the model consists of the number of households, total population, and population by three different age groups. A user may change any of these.

New demographic data influences the forecast in two ways. The new level for demographic statistics for a single year affects many of the forecast equations. Secondly, and in some ways more importantly, the year-to-year change in the demographic data also impacts the forecast. By typing in new data a user alters the growth rates of households and population. This directly affects the forecast for housing, schools, roads, and other forms of construction.

The demographic data are exogenous. The model does not automatically adjust a county's total population for any change a user might make to the population of one age group. Likewise, the model does not reconcile the number of households for changes made to the total population.

It is up to the user running a scenario to insert data that are consistent. This may be done by maintaining the demographic ratios of the original forecast. The user simply divides the population by all three age groups and the number of households by the total population for each year new data is going to be inserted. Once the data are put in, the user adjusts the remaining demographic data so that it conforms with the original ratios.

In some cases, this ratio method is inappropriate. The ratio of households to population, for instance, tends to be higher in counties where the share of residents over 64 years of age is very high. If a user runs a scenario where the size of this age group is increased, consideration must be given to increasing the number of households relative to the total population.

When demographic data are raised the aggregate consumption forecasts for all major categories of construction go up. There is a significant and direct impact on housing. Road mileage rises slightly, however, aggregate use per mile of road increases much more. That is because of the need for road improvements, widening, and repaving of gravel surfaces with asphalt.

Changing the Personal Income Variable

Personal income is an exogenous variable. Users can change it by typing in new data for personal income per capita on line 63. This feeds into the model's calculations for household and total county personal income.

If personal income is raised, the forecast for the construction of site-built single family homes will go up while fewer manufactured homes are put in-place. There is also a slight increase in road mileage.

More significant changes occur in income sensitive areas of construction. Manufacturing, office, retail, warehouse, and municipal building construction all benefit from higher personal income. Aggregate consumption for repairs, maintenance, and improvements also goes up.

Modifying a Model for a Different County

A model can be modified so that it forecasts aggregate consumption for a different region. If the objective is to forecast consumption for a state, a different model should be created for each county or, at least, each geographic region. Doing so would improve the accuracy of the forecast.

Three steps are outlined for modifying a model to fit a different state or region. A user could do just the first step, or the first and second. The reliability of the final product improves as more steps are taken. There is a trade-off in time and cost, however. The models for Oregon's counties, for instance, took two years to complete.

The first step in modifying a model is to replace the county data with the appropriate data for the new county or region you wish to forecast. Both historical and exogenous data should be replaced. This includes:

- Forecast and recent history of the number of households in the state
- Forecast and recent history of the number of seasonal housing units in the state expressed as a percentage of the number of households.
- Recent historical data on county road mileage by surface type and ownership class.
- History and forecast of total county population and a breakdown by the age groups.
- History and forecast of the number of households in the county.
- History and forecast of real personal income per capita in the county in 1987 dollars.
- Recent historical housing balance data for the county. The balance must be counted in two ways. The first way includes the number of occupied, seasonal, and vacant housing units. The sum of these equals the second part of the balance, which is the inventory of housing. It is the sum of the number of site-built single family homes, low-rise multifamily units, high-rise multifamily units, manufactured homes, and other housing.
- History and forecast of mail line and short line railroad mileage in the county. Included in this are commuter railroads.

- The actual or historic value data noted on the list in Table Chapter Three -1.

Table Chapter Three -1

County Adjustment Factors and Constants

Constant	*Mnemonic in this Report*	*Natural Value*	*Model Location*
Land Area	$AREA_C$	Actual	B7
1983 - 93 Avg. Area of new single family houses	$AVGSFSQFT_C$	Actual	B8
Projected ratio of refrigerated to non-refrigerated warehouse construction	$RWPCT_C$	Historic Value	B9
Dummy variable (1 = wet climate region)	$DWEST_C$	1 or 0	B10
Dummy variable (1 = interstate highway access)	$DI584_C$	1 or 0	B11
Bridge adjustment factor	$CAFBRI_{C,T}$	1	B12
Dummy variable (1 = port authority in county)	$DVARPORT_C$	1 or 0	B13
Dummy variable (1 = commercial airport in county)	$DCOMAIR_C$	1 or 0	B14
Projected ratio of airport building construction per household	$AIRBR_C$	Historic Value	B15
Adjustment factor for sidewalks & parking	$CAFSWP_C$	0	B16
% of households in 1990 living in towns, cities, and suburbs		Actual	B17
County or regions projected share of new vacation homes to be built in state	$PSNVH_C$	exogenous forecast	B18
Adjustment factor - warehouses	$CAFWH_C$	0	B19
Adjustment factor - multifamily housing	$MFADJ_C$	0	B20
Projected 2050 share of "other" housing	OTH_C		B21
Adjustment factor - concrete roads	$CAFCR_C$	0	B22
Adjustment factor - gravel roads	$CAFAGR_C$	0	B23
1993 Industrial timber harvest		Actual	B24
1993 other private timber harvest		Actual	B25
Adjustment factor - office buildings.	$CAFO_C$	0	B26
Adjustment factor - manufacturing	$CAFMANF_C$	0	B27
Adjustment factor - retail buildings.	$CAFRET_C$	0	B28
Adjustment factor - public assembly buildings	$CAFPA_C$	0	B29
Adjustment factor - hotels and lodging	$CAFHOT_C$	0	B30
Adjustment factor - misc. Non-residential buildings	$CAFMNRB_C$	0	B31
Adjustment factor - detention centers	$CAFDET_C$	0	B32
Adjustment factor - heat & power	$CAFPOW_C$	0	B33
1993 aggregate recycling share		Actual	B34
2050 aggregate recycling share		exogenous forecast	B35
Adjustment factor - municipal buildings.	$CAFMUNI_C$	0	B36
1991 college student population	$CSPOP_C$		B37
1978 - 94 Avg. Dam construction spending	$AVGDC_C$	Actual	B38
Adjustment factor - miscellaneous Non-building construction	$CAFMNB_C$	0	B39
Adjustment factor - river & marine	$CAFRIVMAR_C$	0	B40
Road usage adjustment	$CARU_C$	1	B41
1994 aggregate use by farms, ranches, and other agricultural buildings	$FARM_C$	Actual	B42

The models contain adjustment factors that were developed by comparing the actual and fitted values of equations. These equations were estimated using historical data on Oregon's 36 counties. Each county in Oregon has a different set of adjustment factors. To modify an Oregon county model for another region, the adjustments should be replaced with those appropriate for the region. Doing this requires estimating new equations for all the counties in the region. Alternatively, a user may wish to simply eliminate the adjustment factors by replacing them with the natural values shown on Table Chapter Three -1.

The second step in modifying a model is the process of verification. Much of the consumption of aggregate is the result of hidden construction activity. Data on housing starts and new building construction is generally available, and we can estimate how much aggregate is used for these. Data on uses such as repairs, improvements, railroad work, agriculture, street repair, and building maintenance projects are not accessible. Estimating aggregate consumption for these categories is difficult.

In the development of the model for Oregon's counties, survey data on the production and apparent consumption of aggregate proved to be extremely valuable. A thorough survey of mines in the state provided data on production and reasonable estimates of flows in and out of counties. Estimates of a few non-reporting mines, recycling, minor sources, and non-commercial production were factored into the analysis. Doing this gave us actual consumption figures by county for a recent year.

The actual consumption figures were compared to construction data from FW Dodge and road data. The road data included a survey of road departments that supplied information on aggregate consumption for the year. By estimating consumption for the known areas of construction from FW Dodge and the road departments, we were able to estimate the amount of aggregate consumed by other, more difficult to measure sectors of the market. The base year data also gave the information needed to identify potential problems in usage factor estimates. This was used to solicit useful feedback from construction contractors.

The third step requires the collection of historical data so that regression equations can be re-estimated. For the Oregon county models, 16 years of data were used. This included construction data from FW Dodge, housing data compiled from several sources, population and income data, and road mileage statistics.

The re-estimation process can be done by using the equation structures shown in the Oregon county models and running new regressions using data on the counties of the other region. The regression for Oregon were done using 16-year averages for each county and then regressing all the counties in one equation. This worked best for the state. In other regions, it may be possible to use time series regressions where a separate equation is run for each county.

Once equations are re-estimated, they can be inserted in the model. The user may then wish to adjust the aggregate usage factors so that they better fit construction practices in the region being modeled.