OREGON **DEPARTMENT OF TRANSPORTATION**

STUDDED TIRES IN OREGON

Analysis of Pavement Wear and Cost of Mitigation

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A comprehensive analysis of the financial impact of studded tires on Oregon highways.

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Foreword and Acknowledgments

This project has been a collective effort of a large group of people. Without their effort, this study would not have been possible. The large amount of data requirement and analysis was probably enough to discourage many from continuing the work. However, all the people who contributed were determined and eager to bring this effort to fruition.

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Executive Summary

This study examines the effects of studded tires on Oregon highways. It does not emphasize the advantages or drawbacks of studded tires in the areas of safety, environmental impacts, or other externalities. The focus of this research is quantifying the degree by which studded tires cause pavement damage. In addition to the rate of rutting, this study examined several categories of costs that result from studded tire use.

The use of studded tires in Oregon continued to grow in popularity during the nineties. A survey conducted in 1995 revealed that about 16 percent of registered vehicles in Oregon were equipped with studded tires during the 1994-95 winter. Nearly half of users had studded tires on both axles. This yields an estimated 1.24 million studded tires in use during the year

Wide ranges of wear rates were found for various sections of PCC and asphalt pavements. This reflects the many factors that contribute to pavement rutting susceptibility. PCC is more resistant to rutting than asphalt. Within the asphalt pavements, there was no obvious advantage of open-graded mixes over dense-graded mixes. The PCC wear rate is about 0.0093 inches per 100,000 studded tire passes, while the wear rate of asphalt pavement is about 0.0386 inches per 100,000 studded tire passes

Three different cost categories of studded tire damage mitigation were identified. However, the expenditure projections for mitigating studded tire damage might be the most important estimate for policy purposes. This expenditure was first estimated for the period spanning 11 years from 1995 to 2005. An adjustment for lightweight studs was factored in. A further adjustment for the new shorter studded tire season as well as the new trend of using studs on both axles was also calculated. Several scenarios are included in this study, but the base case scenario for these estimates predicts an annual average expenditures of about $7 million from the year 2000 up to the year 2005. These estimates are only for the State Highway System and exclusive of any amounts to be spent by the cities and counties on their road systems. It is important to note that project costs might include other construction aspects, or damage after most of the pavements

useful life had elapsed, that are not part of studded tire damage mitigation. Consequently, the project costs might appear different from the damage mitigation costs.

Chapter 1

Introduction

There is an ongoing debate about the use and effects of studded snow tires. Some drivers consider them essential for winter driving and enjoy a sense of increased safety and overall improvement in driving performance in winter conditions. Conversely, it has been well demonstrated that studded tires can cause rapid deterioration of pavements, which in itself poses safety hazards. This pavement damage has forced highway agencies around the nation to increase their maintenance expenditures for highway surfaces.

This report constitutes the most comprehensive cost analysis of studded tire pavement damage ever conducted in Oregon. Work on this study started at the end of 1995, and took more than two and a half years to collect and analyze all the relevant data. Unfortunately, many pressing duties and other work prevented the completion of this study until now. Although the study uses 1995 data as a base year, the passage of a few years has not diminished its importance or relevance. Publishing this study now will add significantly to the literature on studded tires and to the general discipline of highway finance and economic research. In addition, the analysis of annual expenditures for the mitigation of studded tire damage forecasts those costs up to the year 2005. The models in the study were built to accommodate future updates, and reproduce cost estimates for later years.

1.1 Studded Tires Damage Cost Estimates in Oregon

In 1974, a report by the Highway Division of the Oregon Department of Transportation (ODOT) estimated that increased expenditures due to the studded tire damage would cost approximately $1.4 to $2.5 million each year. This estimate has provided the basis for ODOT's estimates of studded tire damage in its periodic studies of highway cost responsibility. In the 1992 *Cost Responsibility Study* (CRS), the annual cost of studded tire damage was estimated at $2.5 million (ODOT, 1992).

During the early 1990s, studded tire damage to Oregon roads became increasingly evident. This damage was particularly severe along the state's high volume interstate system. The increasing severity of the damage prompted ODOT to re-examine its estimate of repair costs attributable to studded tire damage. The 1994 preliminary study conducted by ODOT's Financial Services Branch estimated that if all the studded tire damage in Oregon during 1993 were repaired, the cost would reach $42 million (Malik, 1994). Realizing that not all the damage caused by studded tires lead to a premature failure of pavement, the 1994 update of the Cost Responsibility Study (CRS) adopted an estimate of $11 million (ODOT, 1995) as the amount of annual expenditures attributed to studded tire damage. The study that is presented in this report represents a more thorough effort to corroborate previous findings and determine the damage, cost and expenditures to alleviate studded tires effects on Oregon roads.

It is important to mention that since the 1994 ODOT preliminary study, there have been a peak in the interest of the subject of studded tires. Several researchers have contacted ODOT for data and collaboration on researching this issue. Partial uses of the data in this research were the basis for two master degree theses, one in the field of civil engineering (Brunette, 1995), and the other in the field of economics/industrial engineering (Gray 1997).

1.2 Research Approach

Early stages of the research included determining the method of collecting rut depth data. Once the method of collecting the data was determined, rut depth measurements for 250 highway miles were collected. The level of studded tire use in Oregon was determined by utilizing two methods, parking lot and household telephone surveys. The resulting analyses were next combined with traffic data (for total traffic counts), seasonal volume and traffic composition (fraction of passenger vehicles) to determine studded tire traffic. Estimates for studded tire traffic were then regressed against the rut depth measurements in order to estimate the rate of pavement wear from studded tires for Portland cement concrete (PCC) and two types of asphalt pavements (F-mix and B-mix). The wear rate estimates produces a rate of rutting in fractions of an inch for each 100,000 studded tire passes.

The wear rate estimates were then applied to traffic data for the entire Highway System to determine rut depth for each highway segment. Each highway is segmented at the points where the traffic volumes change. The pavement rutting was then used to estimate the cost of mitigating the damage. Three types of cost estimates were defined in this study. First: *Estimated Cost of Mitigating Total Damage* provides a measure of all pavement damage from 1995, expressed in terms of resurfacing costs, including rutting on highways with very low traffic volumes and studded tire use. This is a revision to the methodology used in the previous study (Malik 1994). The new total damage cost was adjusted for the improved data of studded tire use and the new wear rate estimates. The second cost definition is *Effective Damage Cost*. Effective damage is defined as damage that is expected to reduce the useful life of the pavement. Thus, the effective damage is the annualized cost of pavement repair equivalent to the shortened useful life of the pavement. Finally, growth factors for traffic and studded tire use were used to project *Annual Expenditures* for repair of studded tire pavement damage through the year 2005. The annual expenditures are estimated as the pavement repair costs at the year when the repairs become necessary or the rut depth reaches the critical level. The annual expenditure estimates were then adjusted to account for the impact of lightweight studs.

All of the traffic count data and cost estimation procedures are limited to the state highway system. Only the *Total Damage cost estimate* is extended in a general way to include city streets and county roads.

1.3 Summary of Contents

Chapter Two provides a brief background of studded tires, including a review of research findings about direct and indirect safety effects and a summary of past cost analyses conducted in the U.S.

Chapter Three describes the telephone and parking lot surveys conducted to determine the level of studded tire use in Oregon.

Chapter Four describes the method of estimating wear rate, including sources and procedures for generating rut depth and traffic data.

Cost estimates are provided in Chapter Five. The *Total Damage* cost estimate includes all studded tires rutting for 1995. The *Effective Damage* estimate includes only rutting occurring in 1995 that is sufficient to reduce the useful life of the pavement surface. Finally, projections of mitigation expenditures are provided through the year 2005. The projected expenditure estimate is then adjusted to account for the recent lightweight studs mandate.

Chapter Six provides a summary of the study's major findings.

Recommendations and conclusions are given in Chapter Seven.

Chapter 2

Background on Studded Tires

Studded tires were introduced in North America in 1963 and quickly gained popularity with drivers, due to a perception of improved traction and braking performance under winter driving conditions. By 1972, studded tire use had reached or exceeded 30 percent of passenger vehicles in more than a dozen states. Alaska, Montana and Vermont registered around 60 percent of passenger vehicles using studded tires (NCHRP 32). In Oregon, studded tire use was legalized in 1967, and by the winter of 1973-74 an estimated 9.2 percent of passenger vehicles were equipped with studded tires (ODOT, 1974). In many Canadian provinces and American states, including Oregon, the use of studded tires has been associated with severe pavement damage, mostly in the form of rutting along the wheel tracks. Barter (1996) describes the mechanism of studded tire pavement damage as follows:

> As the tire and stud move over the pavement, there are measurable “spikes” in force at the beginning and end of contact. During these spikes, energy is transferred to the pavement in the form of scratching. Between these energy spikes, the studs have a “punching” action that breaks up aggregate and picks out asphalt.

2.1 Safety Effects of Studded Tires and Pavement Damage

This study does not attempt to quantify or in any way evaluate the performance and safety effects of studded tire use. However, some understanding of the related safety issues can provide a helpful backdrop to the cost analyses undertaken.

Although it has been well established that studded tire traffic causes pavement damage, proponents of studded tires often justify this drawback with assertions of safety benefits for winter driving. Several studies were conducted in the 1970s regarding the safety benefits of studded tires, particularly with regard to braking and traction performance. Research has supported claims of improved performance on ice. However, on bare roads the use of studded tires shows no significant effects on asphalt, and can actually weaken performance on concrete. These findings have been substantiated by more studies (MinnDOT, 1971; NCHRP, 1975; NCHRP 1978; Lu, 1994; Kallberg, 1996).

Wheel track rutting and other forms of pavement damage caused by studded tires pose numerous safety hazards. Wet weather hazards from rutting include increased potential for hydroplaning, as well as splash and spray of water onto windshields of passing vehicles. Studded tires also cause premature abrasion of paint markings and surface friction. Other hazards from studded tire pavement damage include adverse steering effects, lateral lane displacement of vehicles, maintenance hazards, and accelerated degradation of vehicle components (NCHRP, 1977). In freezing temperatures, the collected water can freeze (black ice) and cause slipping. An abundance of motorist complaints and anecdotal information exists regarding these problems, but there is very little quantifiable evidence regarding decreased road safety due to ruts, probably because so many factors can contribute to accidents (Barter, 1996; Lu, 1994). Highway officials in Oregon recommended a ban on studded tires in 1974. During the 1970s, researchers in several other states, including Iowa, Connecticut, and Pennsylvania determined that studded tires produced a net safety hazard and recommended that they be banned (Iowa, 1979; Christman, 1978; Mellot, 1974). In 1974, a Federal Highway Administration memo urged all states to consider banning or limiting the use of studded tires. In Japan, studded tires were prohibited due to concerns about dust pollution (Konagai, 1993).

Not all externalities from studded tires are negative. In freezing temperatures, studded tires can cause roughening of icy road surfaces, which improves traction for all motorists. All-season radials would result in polishing highway ice, making it more slippery (Barter, 1996). Contrary to U.S. studies, results of a recent $30 million, multi-year research program undertaken by the Scandinavian countries indicate that a ban on studded tires would not result in an increase in fatal traffic accidents, but that non-fatal accidents would increase by 30 percent (Barter, 1996). In Finland, where 95 percent of drivers use studded tires, researchers determined that if only half the cars were equipped with studded tires and everything else remained unchanged, the number of injury accidents would increase by 17 percent (Kallberg, 1996). Another study comparing different levels of studded tire use and road salting determined that the almost universal studded tire use in Finland is the socioeconomic optimum, despite the drawbacks. High accident costs were noted as playing a significant role in this outcome (Leppanen, 1996).

2.2 Survey of State Agencies

A survey was conducted in 1995 of all highway agencies in the other 49 states. The questioner inquired about whether they allow studded tires on their highway systems, and the degree to which they monitor damages and expenses caused by studded tires. Most of the states (48) responded. Thirty-five states allow some kind of use of studded tires on their highway systems, and ten states disallow their use (Georgia, Hawaii, Indiana, Kentucky, Louisiana, Michigan, South Carolina, Texas, Virginia, and Wisconsin). Three states allow partial use of studded tires. Illinois and Minnesota allow only postal carriers to use studded tires, and Maryland allows studded tire use in its western counties only.

Out of the 35 responding states that allow studded tires, 11 have estimated costs from studded tire pavement damage. Only Alaska and Colorado periodically update their estimates, but Colorado does not have an established methodology. Only Alaska collects regular data on the level of studded tire use in the state, and it was also the only state that budgets for studded tire damage repair. A summary of findings from the state agency survey is provided in Table 2.1.

Table 2.1 Summary of the survey of other States

	question	Number Yes	No	Other	Percent Yes	No	Other	No Ans.	Total	Comments (other)
1	Is it legal for passenger cars to use studded tires in your state?	32	11	2	65%	22%	4%	4	49	mail carriers only - 2
1a	If yes, do you have an estimate of how many or the percentage of cars that use studded tires in your state?	9	27	1	18%	55%	2%	12	49	mail carriers only 1
1b	If yes, are these estimates updated periodically or regularly?	1	30		2%	63%	0%	17	48	Alaska only
1c	If yes, do you have an established methodology for updating?	1	30		2%	63%	0%	17	48	
2	Do you have an estimate of the damages caused by studded tires?	10	35		20%	71%	0%	4	49	
2a	If yes is this estimate periodically or regularly updated?	2	19		4%	39%	0%	28	49	
2b	If yes, do you have an established methodology or model for estimating these damages?	1	23		2%	47%	0%	25	49	only Alaska
3	Do you have an estimate of the annual expenditures to mitigate damages caused by studded tires?	3	42		6%	86%	0%	4	49	
4	Does your agency budget or program for studded tire damage repair?	1	42		2%	89%	0%	4	47	
5	Are you aware of any trucks or other heavy vehicles that use studded tires in your state?	5	40		11%	85%	0%	2	47	

2.3 Highway Agencies Expenses for Mitigating Studded Tires Pavement Damage

In order to minimize the hazardous effects of pavement damage caused by studded tires, many state highway agencies have increased mitigation expenditures. Of the 35 states that currently allow the use of studded tires, only Alaska has an established methodology for regularly updating its cost estimates (agency survey). The annual cost of mitigating studded tire damage to Alaskan roads was recently estimated at $5 million, of which $1 million is attributed to illegal studded tire use during summer months (Barter, 1996).

Several states conducted cost analyses during the 1970s. Massachusetts and Wisconsin estimated annual costs of $3.37 million and $12 million respectively (Massachusetts, 1973; Lyford, 1977). The state of Washington estimated that studded tire damage costs were $3.5 million in 1984 (survey). These and other cost estimates are summarized in Table 2.2. Oregon, as mentioned in chapter 1, had several estimates in different years.

Table 2.2 Summary of past studies on costs of studded tire pavement damage

State	Expenditure estimates
Washington (survey)	Estimated costs for 1984 were $3.5 million
Alaska, 1996	$5 million a year ($1 million summer damage)
Minnesota, 1971	$55 million for the1973-80 period
Massachusetts, 1973	$3.37 million for 1973
Missouri, 1976	$170 million for 30-year analysis period
Wisconsin, 1977	Over $12 million annually; 25-year analysis period

Chapter 3

Studded Tires in Oregon

Several studies and data collection efforts concerning the use of studded tires in Oregon were identified. ODOT estimates of studded tire use have been documented for the winters ending in 1974, 1984, 1989, and 1990. Brunette (1995) undertook a relatively small data sampling and augmented some of the new ODOT parking lot data to develop estimates of the level of studded tire use. For the purpose of this study, a parking lot survey and an extensive telephone survey were conducted. The survey methods are discussed in general terms below. The estimates for historic studded tire use are summarized in Table 3.1.

3.1 Previous Studies on Studded Tire Use in Oregon

The earliest estimates for studded tire use in Oregon were derived by ODOT and are described in the 1974 report. Moving traffic counts were taken on 25 state highways during the winters of 1971-72, 1972-73, and 1973-74 in which studded tire traffic was audibly distinguished from non-studded tire traffic. The fractions of vehicles using studded tires at each location were grouped into four different “zones” and used to calculate a statewide average value, “taking into account the vehicle miles driven in the various zones.” The statewide average was 9.2 percent, with individual location values ranging from 1.21 percent on Highway 101 along the Oregon coast to 22.93 percent on I-80N, near Baker.

Moving traffic counts were again used in 1984, 1989 and 1990. The use of studded tires during these years showed some decline. However, a parking lot survey taken in 1990 showed a marked difference, indicating an increase over 1974 levels.

Table 3.1 Historic studded tire use estimates for Oregon

Zone	1973-74	1983-84	1983-84	Dec. 1989	Mar. 1990	Mar. 1990 Parking lot
1	1.5%	3.9%	1.5%	1.6%	1.8%	0.0%
2	4.3%	2.8%	3.4%	3.4%	2.7%	5.3%
3	11.0%	5.8%	5.5%	1.5%	2.7%	10.0%
4	15.0%	11.6%	14.2%	8.0%	14.2%	24.0%
Statewide	**9.2%**	**6.7%**	**6.6%**	**3.4%**	**6.1%**	**11.5%**

3.2 Current Estimates of Studded Tire Use in Oregon

During the 1994-95 winter, Brunette conducted moving traffic surveys at three locations (two in Corvallis, and one in Philomath). He also collected studded tire observations from parking lots in the Corvallis area, as well as using parking lot data gathered by ODOT. Collecting data on parked cars allowed surveyors to determine the axles on which

studded tires were mounted. In earlier years, most vehicles used studded tires on only one axle. According to the parking lot data, approximately half of all vehicles using studded tires had them on both axles, effectively doubling the studded tire passes for those vehicles. Brunette estimates the statewide average use of studded tires at 23.8 percent, with regional rates ranging from 65.7

percent (ODOT-Region 4) to 7.4 percent (ODOT-Region 3). Note that the increase over the 1974 study is due in part to the doubling effect from using studded tires on both axles.

For the purpose of this study, two survey methods were employed to estimate the level of studded tire use in Oregon. First, a parking lot survey was conducted. Much of this data was shared with Brunette as described above. Then, in early 1996, a telephone survey was conducted of a sample of Oregon households. These studies are described below. The most recent estimates are summarized in Table 3.2

Table 3.2 Recent studded tire use estimates for Oregon

No Monthly Adjustment

	Total Vehicles Surveyed	Vehicles Using Studs	Nominal use	Vehicles Using 4 studs	Effective use
Region 1	1615	269	16.66%	122	24.21%
Region 2	1211	150	12.39%	68	18.00%
Region 3	811	41	5.06%	22	7.77%
Region 4	1385	444	32.06%	265	51.19%
Region 5	1281	342	26.70%	185	41.14%
Statewide	**6303**	**1246**	**19.77%**	**662**	**30.27%**

3.2.1 Parking Lot Survey Results

During the winter of 1994-95, ODOT conducted a parking lot survey of studded tire use in Oregon. Heavily utilized parking areas, mostly at shopping centers, were selected at various locations to represent ODOT’s five regions. At each parking location and at each time, data were collected from 200 parked cars, indicating if the vehicle had 2-wheel or 4-wheel drive, and if studded tires were mounted on the front, rear, or both axles.

In most cases, six visits were made to each location. In a few cases in Region 4, only three visits were made. All of the visits took place between the last week of November and the end of March. No visits took place during April, although studded tire use was permitted during that month. Summary results of the parking lot survey are shown in Table 3.3.

Table 3.3 Summary of the parking lot survey.

Region 1	**studs**	**4 studs**	**Effective**	**Days**	**Wt Fctr**
Date: December 12 1994	14.17%	6.00%	20.17%	31	6.251667
Date: January, 5, 1995	12.83%	6.00%	18.83%	31	5.838333
Date: January 26, 1995	12.00%	4.50%	16.50%	31	5.115
Date: February 16, 1995	13.83%	6.00%	19.83%	28	5.553333
Date: March 8, 1995	8.50%	3.67%	12.17%	31	3.771667
Date: March 29, 1995	5.50%	3.50%	9.00%	31	2.79
Effective studded tires use					**16.02%**
Region 2	**studs**	**4 studs**	**Effective**	**Days**	**Wt Fctr**
Date: December 13, 1994	11.24%	4.87%	16.11%	31	4.99359
Date: Jan. 4, 1995	10.70%	5.33%	16.02%	31	4.967506
Date: January 25, 1995	10.68%	4.86%	15.55%	31	4.819091
Date: February 16, 1995	12.80%	6.20%	19.00%	28	5.32
Date: March 7, Eugene	11.00%	5.50%	16.50%	31	5.115
Date: March 27, 1995	5.09%	1.82%	6.91%	31	2.141818
Effective studded tires use					**14.95%**

Region 3	**studs**	**4 studs**	**Effective**	**Days**	**Wt Fctr**
Date: November 29, 1994	4.90%	2.70%	7.60%	30	2.280597
Date: December 19, 1994	6.00%	4.00%	10.00%	31	3.1
Date: January 10, 1995	3.50%	2.50%	6.00%	31	1.86
Date: February 2, 1995	3.00%	2.33%	5.33%	28	1.493333
Date: February 24, 1995	3.50%	2.00%	5.50%	31	1.705
Date: March 23, 1995	3.50%	1.67%	5.17%	31	1.601667
Effective studded tires use					**6.62%**

Region 4	studs	4 studs	Effective	Days	Wt Fctr
Date: January 20, 1995	30.95%	15.19%	46.14%	31	14.30296
Date: February 16, 1995	23.45%	11.89%	35.34%	31	10.95587
Date: March 2, 1995	27.43%	14.62%	42.04%	31	13.0331
Date: March 17, 1995	18.35%	6.96%	25.31%	28	7.085642
Effective studded tires use					**37.50%**

Region 5	studs	4 studs	Effective	Days	Wt Fctr
Date: November 28, 1994	33.88%	18.13%	52.00%	30	15.6
Date: December 21, 1994	35.38%	20.13%	55.50%	31	17.205
Date: January 26, 1995	37.38%	19.75%	57.13%	31	17.70875
Date: February 23, 1995	34.50%	21.00%	55.50%	28	15.54
Date: March 14, 1995	22.00%	11.63%	33.63%	31	10.42375
Effective studded tires use					**50.65%**

The parking lot survey results indicate an average statewide level of studded tire use of 18.15 percent, ranging from 50.7 percent in Region 5 to 6.6 percent in Region 3. The estimates derived by ODOT are consistently lower than Brunette's estimates. The discrepancy is likely explained by the fact that Brunette's estimates did not utilize data gathered toward the end of the studded tire season, when the use of studded tires falls considerably.

3.2.2 Household Telephone Survey Results

In 1995, ODOT contracted with the Oregon Survey Research Laboratory (OSRL) at the University of Oregon to conduct a random sample telephone survey to ascertain the level of studded tire use in Oregon. The surveyors contacted 3,107 households, which collectively owned 6,329 vehicles. The households were chosen to represent a balanced sample from all of Oregon's 36 counties, as well as Clark County in the State of Washington. The results were then matched up to ODOT's five regions (service areas in the state, Figure, 3.1). This survey represents the most comprehensive information available on the use of studded tires in Oregon. The results did not only give the use patterns and percentages, but they also deduce the growth rates of studded tire use by Oregon residents. Results of the summaries of regional use from the household survey are shown in Table 3.4. Another summarized look is also presented in chapter 4, Table 4.8.

Table 3.4 Household telephone survey results summarized regionally.

REGION 1 SUMMARY				w/ studs	days/mo	monthly use	wt factor
Using Studs	269	16.7%	NOV	133	30	8.2%	2.47
No Studs	1346	83.3%	DEC	214	30	13.3%	3.98
Total vehicles	1615		JAN	232	31	14.4%	4.45
			FEB	235	28	14.6%	4.07
2 studs		53.2%	MAR	183	31	11.3%	3.51
4 studs		45.4%	APR	43	30	2.7%	0.80
							10.7%
			Effective stud use				**15.6%**
REGION 2 SUMMARY				w/ studs	days/mo	monthly use	wt factor
Using Studs	150	12.4%	NOV	93	30	7.7%	2.30
No Studs	1061	87.6%	DEC	127	30	10.5%	3.15
Total vehicles	1211		JAN	130	31	10.7%	3.33
			FEB	134	28	11.1%	3.10
2 studs		53.3%	MAR	112	31	9.2%	2.87
4 studs		45.3%	APR	24	30	2.0%	0.59
							8.5%
			Effective stud use				**12.4%**
REGION 3 SUMMARY				w/ studs	days/mo	monthly use	wt factor
Using Studs	41	5.1%	NOV	28	30	3.5%	1.04
No Studs	770	94.9%	DEC	38	30	4.7%	1.41
Total vehicles	811		JAN	36	31	4.4%	1.38
			FEB	32	28	3.9%	1.10
2 studs		43.9%	MAR	30	31	3.7%	1.15
4 studs		53.7%	APR	8	30	1.0%	0.30
							3.5%

			Effective stud use					**5.4%**
REGION 4 SUMMARY				w/ studs	days/mo	monthly use		wt factor
Using Studs	444	32.1%	NOV	342	30	24.7%		7.41
No Studs	941	67.9%	DEC	415	30	30.0%		8.99
Total vehicles	1385		JAN	418	31	30.2%		9.36
			FEB	410	28	29.6%		8.29
2 studs		40.3%	MAR	353	31	25.5%		7.90
4 studs		59.7%	APR	149	30	10.8%		3.23
								25.1%
			Effective stud use					**40.1%**
REGION5 SUMMARY				w/ studs	days/mo	monthly use		wt factor
Using Studs	342	26.7%	NOV	261	30	20.4%		6.11
No Studs	939	73.3%	DEC	323	30	25.2%		7.56
Total vehicles	1281		JAN	314	31	24.5%		7.60
			FEB	297	28	23.2%		6.49
2 studs		45.3%	MAR	230	31	18.0%		5.57
4 studs		54.1%	APR	83	30	6.5%		1.94
								19.6%
			Effective stud use					**30.2%**

After making adjustments for vehicles with studded tires on both axles, and for varying levels of use during different months, the statewide average for studded tire traffic was estimated at 16.02 percent. This estimate is lower than both of the parking lot estimates mentioned above. A plausible cause for this discrepancy is that the household survey included the level of use in April, which was usually the lowest level by a wide margin, whereas the parking lot data gathered represented use through March. The inclusion of April has the effect of bringing down the average for the season. The telephone survey indicates that studded tire use falls from 25 percent in March to only 11 percent in April. This would explain the similarity between results for both Brunette's and ODOT parking lot surveys. The telephone survey results after the adjustment for the axles and the monthly use are summarized in Table 3.5. In the table, nominal vehicle represents the percent of vehicles using studded tires. Nominal Axle will be the nominal vehicle multiplied by 1+ the percentage of vehicles using studs on both axles. The effective use is calculated by using the information in Table 4. Where the number of vehicles using studs in a particular month are averaged for the season and then weighted for the number of days in the month. Then, the nominal axle operation is used to calculate the effective stud use.

Figure 3.1

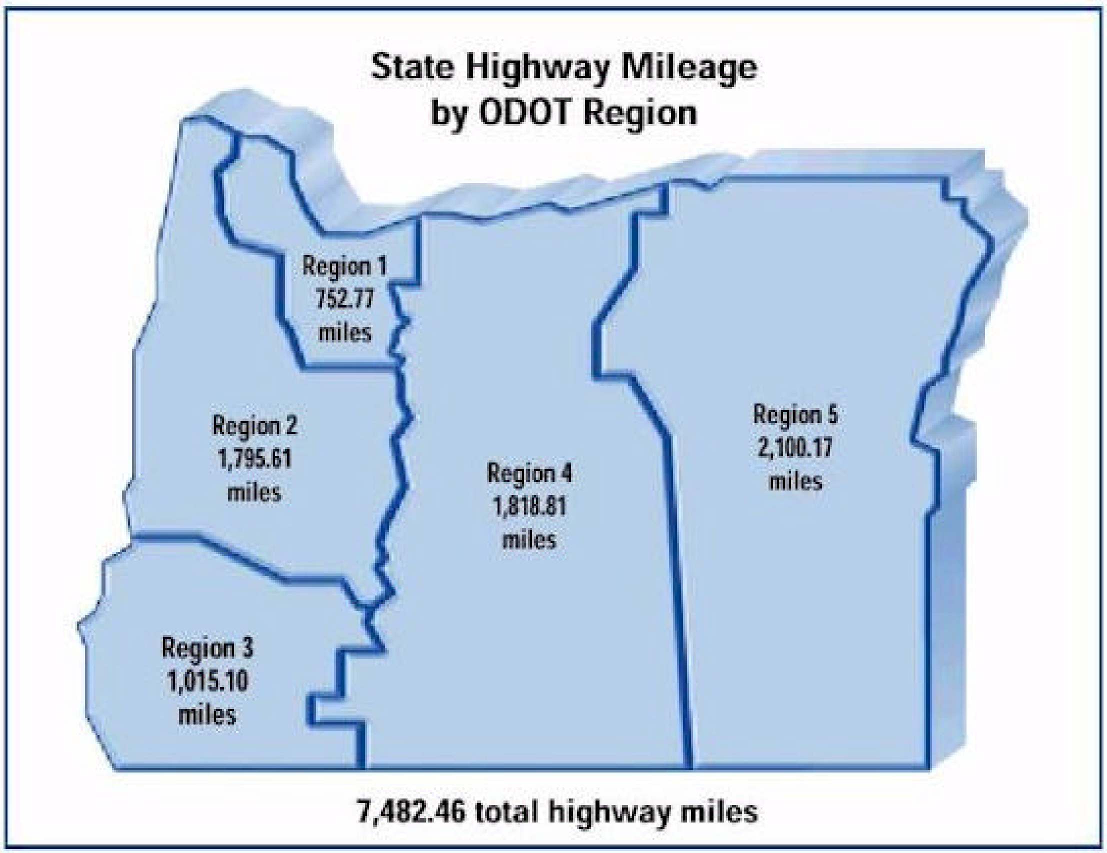


Table 3.5

		Studded Tire Use Rates		
Region	1995 Registered PassVeh. (DMV)	Nominal Vehicle	Nominal Axle	**Effective Use**
1	1,076,477	16.7%	24.2%	15.57%
2	824,776	12.4%	18.0%	12.38%
3	383,955	5.1%	7.8%	5.43%
4	220,851	32.1%	51.2%	40.07%
5	156,695	26.7%	41.1%	30.20%
State Wtd Ave.	**2,662,754**	**15.53%**	**23.15%**	**16.02%**

The biggest disparity between the parking lot and the telephone survey is in the estimate for Region 5. In addition to the effect of including April in the estimates, the proximity of the parking locations to the Idaho border may be responsible for the higher parking lot estimate. The results from the household survey are considered the more reliable and are used for the remaining analysis.

The differences in the three studded tire use estimates for 1995 are shown in Table 3.6. Although there are some differences in the percentages, the general results indicate that we are able to form a very good idea about the use patterns and spread of the use geographically and historically.

Table 3.6 Recent studded tire use estimates for Oregon

Region	**Brunette**	**ODOT Parking lot survey**	**ODOT Telephone survey**
1	21.9%	16.0%	15.6%
2	16.0%	15.0%	12.4%
3	7.4%	6.6%	5.4%
4	65.7%	37.5%	40.1%
5	54.9%	50.7%	30.2%
State average	**23.56%**	**18.15%**	**16.02%**

Chapter 4

Wear Rate Estimation

This chapter describes the model, methodology, data requirements and results of the regression analysis used to estimate the wear rate of studded tires on pavement surfaces. For the purpose of this research, the rate at which studded tire traffic inflicts damage is of primary importance, and the total rut depth is secondary. Total rut depth can be represented as an accumulation and a function of studded tire traffic causing an annual increment of rut. Using that approach, we can make predictions of future rutting under expected future traffic conditions. Additionally, the studded tire damage can be isolated to any given period of time.

Many factors affect the wear rate, including traffic conditions such as speed and acceleration of vehicles; pavement design and materials; and, properties of the studded tires such as the material that the stud is made of, and the number of studs mounted on each tire (Keyser, 1970; Barter, 1996). Table 4.1 lists some of the factors that affect wear rates.

Table 4.1 Factors affecting studded tire wear rate (adapted from Keyser, 1970)

Factor	Characteristic
Pavement	Geometry (turns, intersections) Mix type Material hardness Age
Traffic	Speed Acceleration Deceleration Stopping, starting

Vehicle	Axle weight Stud material and type Number of studs
Environment	Humidity, temperature

4.1 Wear Rate General Model

The rutting caused by studded tires is expressed as a function of studded tire passes over the surface using the following model:

$$\mathbf{R = \boldsymbol{a} * SP}$$

Where,

R = Rut depth estimate.

a = Wear rate,

SP = Studded tire passes occurring on the pavement,

The model employs two simplifying assumptions:

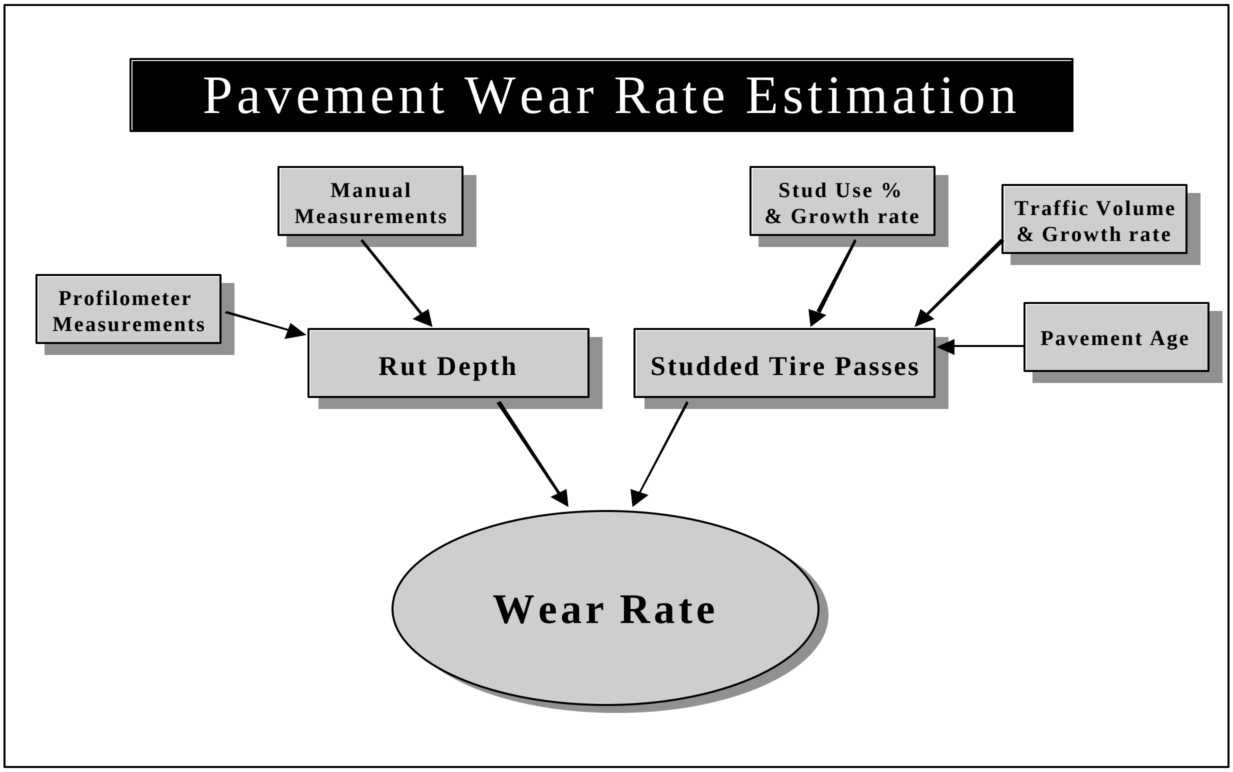
First, the wear rate, a, is assumed constant and not a function of previous damage, time, or past studded tire passes. Some researchers and an early study of studded tire rutting have indicated that pavement surfaces have a higher initial wear rate which stabilizes after 100,000 studded tire passes (Minnesota, 1971). However, most other studies have estimated wear as a constant with respect to time and cumulative traffic. The assumption of a constant wear rate is a generalization because of the high variability and the numerous factors affecting wear in different pavements.

The second assumption is implied by the exclusion of an intercept term and other parameters, suggesting that all rutting is caused by studded tire traffic only. Studies have shown that on both asphalt and PCC, conventional tires produce virtually no measurable wear (Krukar, 1973; Speer, 1971). However, axles of heavy trucks cause rutting on asphalt surfaces, though not on PCC surfaces. This raises some concern about attributing all rutting on asphalt to studded tires. In particular, rutting in the right lane, which tends to be the predominant travel lane for trucks, is likely to be partially caused by truck traffic. This issue is discussed in section 4.3.2.

4.2 Methodology for Wear Rate Estimates:

The task is to estimate the pavement wear rate (***a***) associated with a given number of studded tires passes (i.e., inches per thousands of passes). In order to achieve that goal the two other terms in the equation, namely the rut depth estimates (**R)** and studded tire passes (**SP**), need to be measured and utilized. However, pavement life spans many years, thus it is difficult to isolate one-year's worth of rut wear on any one segment of pavement. Therefore, we need to adjust the equation to account for total observed rut depth that can be measured on single highway segments.

TR = R1 + R2 + R3 +……………..+ Rn



$= \sum Ri \qquad i = 1 \text{ to } n$

Where,

Ri is the Rut depth in year i, and n is the age of the pavement segment.

Thus,

$TR = \sum (a*SP)i$

$= a \sum SPi$

Since SPi represents studded tire passes in year i.

Then,

$\sum SPi$ is the total studded passes for the life of the pavement.

The wear rate general model becomes:

$$\mathbf{TR} = \boldsymbol{a} * \mathbf{SP}^{\mathbf{life}}$$

Where,

SP^{life} = Total studded tire passes occurring during the life of the pavement.

4.2.1 Rut Depth Measurements:

Total rut depth represents damage sustained over the entire life of the pavement surface. A data set of rut depth measurements was collected from several sections of the Oregon state highway system, including two types of asphalt and Portland cement concrete surfaces. Highly accurate measurements of rut depth can be taken manually by placing a straightedge across the wheel track and measuring the distance from its edge to the bottom of the rut. However, the cost in terms of labor, time, traffic obstruction and, most importantly safety hazards prohibit manual generation of very large data sets, especially since the most severe rutting tends to occur on the most highly traveled roads. In order to get the desired volume of rut measurements, the South Dakota Profilometer van was used. The Profilometer van uses acoustic signals to measure wheel path ruts while traveling in traffic at speeds up to 55 mph, allowing enormous amounts of data to be collected without the high safety hazards, and time costs associated with manual measurements. However, due to the high speed, Profilometer measurements are not as accurate as measurements taken manually. Therefore, calibrating the Profilometer measurements was essential to ensure the reliability of the rut depth data.

4.2.1.1 Profilometer Calibration:

A sample of Profilometer measurements was calibrated with a set of manual measurements from the same highway locations. These are referred to as the *test data set*. The highway sections represented in the test data sets are listed in Table 4.2

Table 4.2

Surface	Highway
Asphalt (F-Mix)	I5 South, MP 245 I5 South, MP 243 US 97 South, MP 133.5 US 97 South MP, 140.4
Asphalt (B-Mix)	I5 North MP, 42.75 US 22 East, MP 3 I84 East, MP 20 I84 East, MP 46.5
PCC	I5 North, MP 262 I5 North, MP 278 I5 South, MP 287.5 I205 North, MP 12

Most of the rut measurements were taken on the interstate system in Regions 1 and 2. These highways are characterized by substantial rutting due to high traffic volumes. Two types of asphalt are included in the study: F-mix, which is an *open-graded mix,* favored for good drainage properties in wet weather, and B-mix, which is a conventional dense-graded asphalt mix. Portland Cement Concrete (PCC) surfaces are also included in the data sets.

In order to evaluate the accuracy of the Profilometer readings, the *test data set* was compiled from two lanes of the 12 sections of Oregon highways mentioned above. Each section was about 1/5 of a mile long. Manual measurements were taken (for both left and right wheel tracks) every 25 feet, yielding roughly 40 observations per section. The Profilometer took measurements of both wheel tracks at approximately one-foot intervals (roughly 1,000) for the same sections.

The Profilometer takes simultaneous measurements for both left and right wheel tracks. The observation of the measurement results revealed a large number of negative values for rut measurements, implying mounds rather than ruts, an implication proved false by visual inspection of the roads. In virtually every case, such erroneous measurements were found for only one of the two tracks. It was, therefore, determined that the Profilometer tends to take only one reliable measurement for each cross-sectional location on the roadway. Subsequent analysis used only the deeper of the two wheel track measurements at each measurement location (i.e., only the left or the right wheel rut was used, not both). Both measurements were eliminated in the few instances when both values were negative.

After the data set was reduced to represent only the deeper measured rut, groups of 25 consecutive measurements (feet) were averaged, yielding 40 values for each section. These were then regressed against the 40 manual measurements (true rut depth) for the corresponding (left or right) wheel tracks.

The analysis of this data set indicated that the Profilometer consistently underestimates the actual rut depth by about 6.5 percent.

Figure 4.2 shows the regression analysis of the deepest reading from all three runs of the Profilometer averaged every 1/5 of a mile.

Figure 4.2 Regression results from Profilometer calibration

Regression Statistics	
Multiple R	75%
R Square	56%
Adjusted R Square	54%
Standard Error	0.141
Observations	72

Note: R Square for regression through origin

$$R^2 = 1 - \frac{\sum (\text{res})^2}{\sum y^2{}_i}$$

$R^2 = 0.93$

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.7704	1.7703	89.144307	4.11921E-14
Residual	71	1.4100	0.0199		
Total	72	3.1803			

	Coeff. Est.	*Std. Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Profilometer meas.	1.0240	0.0328	31.2	3.509E-43	0.9585	1.0895

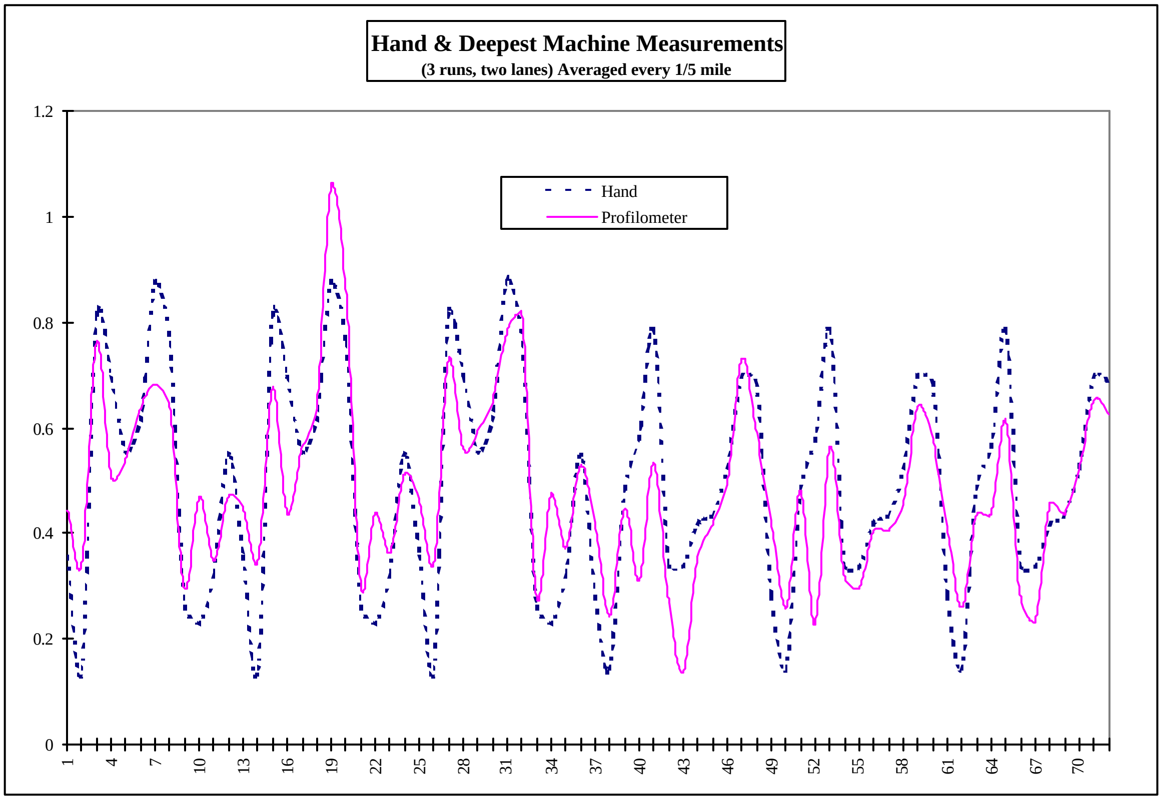
Profilometer adjustment factor, x, is upper limit at when:

$t_{.025,\ 72} = 1.96$
$S^2 = 0.328;$
$S = 0.18$
$n = 72;$
$n^{.5} = 8.48$

$$x = 1.024 + t_{.025,72} * \left(\frac{S}{\sqrt{n}} \right)$$

$$x = 1.065$$

Figure 4.3



4.2.2 Total Rut Depth Data and Measurements (TR)

A data set of rut depth measurements was gathered for about 250 lane miles of Oregon highways. The Profilometer measurements were averaged every 25 feet, and that average constitutes one observation. Based on the earlier findings, Profilometer measurements from Oregon State highways were adjusted by the following calibration equation:

Rut Depth = Profilometer measurement * 1.065

In addition the test (hand measurement) data set was also appended to the Profilometer measurements. The resultant data set constitute the main data set, which was used to estimate pavement wear rates.

Table 4.3 Highway sections used for wear rate estimation

Surface	Main Data Set (Profilometer)	Test Data Set (manual)
Asphalt (F-Mix)	I5 South, MP 234-247	I5 South, MP 245
	I5 South, MP 294-299	I5 South, MP 243
	I84 East, MP 22-31	US 97 South, MP 133.5
	I84 West, MP 22-31	US 97 South MP, 140.4
Asphalt (B-Mix)	I5 North, MP 234-244	I5 North MP, 242.75
	I5 North, MP 244-249	US 22 East, MP 3
	I84 E, MP 17-22	84 East, MP 20
	I84 W, MP 17-22	
PCC	I5 North, MP 259-280	I5 North, MP 262
	I5 South, MP 259-294	I5 North, MP 278
	I205 North, MP 0-25	I5 South, MP 287.5
	I205 South, MP 0-25	I205 North, MP 12

See Appendix A for a more thorough tabulation of rut depth data.

4.3 Methodology for Lifetime Studded Tire Passes (SP^{life})

For each highway section in the rut measurement data set, an estimate was derived for the over the years-cumulative studded tire traffic. First, an estimate for the number of studded tire passes in 1995 was calculated by adjusting total traffic volume data using factors for the relative level of traffic during the studded tire season; the percent of traffic made up of passenger vehicles; and the portion of vehicles using studded tires. Then, historic growth factors for traffic and studded tire use were applied to calculate the studded tire traffic since the construction date of the pavement. This procedure is described below. The sources and methods used to obtain the data are described in Section 4.3.1.

For each highway segment, the following steps were performed:

Step 1. Estimate 1995 Passenger Vehicle Traffic (PVT^{95})

$$PVT^{95} = ADT^{95} * 365 * PV_j$$

Where

ADT^{95} = Average Daily Traffic for 1995,

PV_j = Percent of traffic comprised of passenger vehicles on highway j.

Note that multiple values for ADT apply to each highway section. ADT changes at each exit and entrance point along the highway. All of the highway sections in the data set are long enough to include multiple change points.

Step 2. Estimate passenger vehicle traffic (PVT_m) for each month of the studded tire season

Let months from November through April be designated 1 through 6.

$$PVT_m^{95} = PVT^{95} * T_m \%$$

Where, $T_m\%$ is the percent of annual traffic taking place in month m

Step 3. Estimate the studded tire passes for 1995 by applying monthly studded tire factors (St_m) to the PVT_m; sum to find the annual studded tire traffic:

$$SP_m^{95} = PVT_m^{95} * ST_m$$

Then,

$$SP^{95} = \sum SP_m^{95} \qquad \text{for} \qquad m = 1 \text{ through } 6$$

Step 4. Estimate effective growth in studded tire traffic for the past years of the pavement's life.

Studded tire traffic increases due to growth in both traffic and studded tire use. Traffic growth rates were determined for each highway, while the studded tire growth is the statewide rate. This rate captures increases in both traffic and studded tire use to express the growth over time in studded tire passes as follows:

$$EG = [(1 + TG_j) * (1 + SG)] - 1,$$

where,

EG = Effective statewide growth rate of studded tire traffic,

TG_j = Annual average traffic growth on highway j, and

SG = Statewide annual average growth in studded tire use[1].

---

[1] Example:
Suppose in 1995, annual traffic is 100,000, and effective studded tire use is at 20%, yielding SP^{95} = 20,000. Suppose further that traffic is expected to grow 10% (to 110,000) and studded tire use is expected to increase 5% (to 21%). For SP^{96} we get 21% * 110,000 = 23,100. Or we could simply calculate: (1 + 10%) * (1 + 5%) - 1 = (1.1 * 1.05) - 1 = 15.5% growth in studded tire traffic. Thus, $SP^{96} = SP^{95}$ (1 + 15.5%) = 20,000 * 1.155 = 23,100.

Step 5. Apply the Effective Growth rate and 1995 studded tire passes (SP^{95}) to calculate the lifetime-studded tire passes (SP^{life}) as follows:

Where,

$$SP_{life} = SP_{1994} + SP_{1993} + SP_{1992} + SP_{1991} + ... \; ...... + SP_{i}$$

i = The year i when the pavement section was first constructed.

However,

$SP^{95} = SP^{94} * (1+EG)$

Then $SP^{94} = SP^{95} / (1+EG)$ and $SP^{93} = SP^{95} / (1+EG)^{2}$

Thus, for the general term,

$SP^{n} = SP^{95} / (1+EG)^{n}$

Therefore,

$$SP_{life} = \frac{SP_{95}}{EG} * \left[1 - \frac{1}{(1+EG)^{n}}\right]$$

where, SP^{life} = lifetime studded tire passes, and

n = age of segment in 1995

If age < 29 Else n=28

Age is limited to 28 years to correspond to the number of years that studded tire use has been legal in Oregon.

4.3.1 Data Requirements for Lifetime Stud Passes:

Data on studded tire use were taken from the telephone survey outlined in Section 3.2.2. Traffic data were provided by ODOT's Transportation Data Section and the *1995 Traffic Volume Tables* (ODOT, 1996a). Each data source is described below.

4.3.1.a) Traffic Volumes:

The basic building block for calculating studded tire traffic is the traffic count, or Average Daily Traffic (ADT). These were provided by ODOT's Transportation Data Section. The ADT data were specified for each direction on each highway, and reflect the changing traffic level at each access point. A sample segment from the 1995 edition of ODOT's *Traffic Volume Tables* is shown in Table 4.4.

4.3.1.b) Traffic Seasonal and Passenger Vehicle Distribution:

Other characteristics for traffic were taken from ODOT's *Traffic Volume Tables,* which are published annually. In 1995, ODOT had 116 permanent counters located at various points on the state highway system. For each permanent counter location, data are available on the percent of traffic comprised of passenger vehicles and the relative volume of traffic each month. These factors were taken from the 1995 *Traffic Volume Tables* for highway sections in the data sets, where multiple counters are present along a highway. Where the data was not explicit, extrapolation was used to reach the most appropriate factor based on traffic volume.

Passenger vehicle and monthly traffic factors are shown in Tables 4.5 and 4.6.

Table 4.4 Traffic Volumes by Highway Segment.

COLUMBIA RIVER HIGHWAY #2 (I-84)	MP	North ADTs	South ADTs	(both direction	Lane#
Troutdale Automatic Recorder, Sta. 26-001, on Sandy River Bridge...	17.71	12800	14900	27700	4
0.30 mile east of Jordan Interchange...	18.12	11650	13150	24800	4
0.30 mile east of Corbett Interchange...	22.40	10850	12350	23200	4
0.20 mile east of Rooster Rock State Park Interchange...	25.19	10500	11900	22400	4
0.10 mile east of Bridal Veil connection...	28.18	10300	11800	22100	4
0.50 mile east of Multnomah Falls Interchange...	31.89	10200	11600	21800	4
STADIUM FREEWAY HIGHWAY NO. 61 (I-405)					
0.60 mile west of Pacific Highway (I-5)...	0.60	45300	46600	91900	6
S.W. 4th Avenue Undercrossing...	0.88	42900	46600	89500	6
S.W. Broadway Undercrossing...	1.11	36500	38100	74600	6
S.W. Park Avenue Undercrossing...	1.18	59600	38100	97700	6
		59600	60900	120500	6
S.W. Yamhill Street Undercrossing...	2.02	47100	47200	94300	6
N.W. Glisan Street Undercrossing...	2.45	34200	43800	78000	6
N.W. Kearney Street Overcrossing...	2.65	45900	49300	95200	6
Fremont Bridge Automatic Recorder, Sta. 26-027, 1.16 miles southwest of	3.05	52700	45600	98300	6
EAST PORTLAND FREEWAY #64 (I-205)		N	S		
Stafford Automatic Recorder, Sta. 03-016, 1.27 miles east of	1.27	36200	36500	72700	4
0.40 mile east of Wankers Corner Interchange, (Stafford Road)...	3.56	35600	35800	71400	4
0.60 mile east of 10th Street, South West Linn Interchange...	7.00	37700	37300	75000	4
On Willamette River Bridge, 0.30 mile east of Oswego Highway	9.12	42800	43700	86500	6
0.40 mile east of Pacific Highway East, (ORE99E) Oregon City Interchange	9.69	48400	45500	93900	6
On Clackamas River Bridge, 0.30 mile south of S.E. 82nd Drive	10.75	62700	62100	124800	6
0.40 mile south of Clackamas Highway (ORE224), South Clackamas Interc	12.27	58000	56700	114700	6
M.P. 12.63 to M.P. 13.24 common with Clackamas Highway (ORE213 and	13.09	62900	64300	127200	6
0.20 mile north of S.E. 82nd Drive (ORE213 North Junction),Lake Road Int	13.38	45800	45800	91600	6
0.40 mile south of Sunnyside Road Interchange...	14.18	56100	55300	111400	6
0.40 mile south of Johnson Creek Blvd. Interchange...	15.84	65300	64600	129900	6
0.40 mile south of Foster Road Interchange...	17.45	69900	69200	139100	6
0.30 mile south of Mt. Hood Highway (US26) Interchange...	18.82	72700	71600	144300	6
0.50 mile north of Division Street Interchange...	20.11	78200	76800	155000	6
Burnside Street Undercrossing...	20.87	58000	59200	117200	6
0.20 mile north of Columbia River Highway (I-84) Interchange...	21.77	49600	65700	115300	6
0.40 mile north of connections to Columbia River Highway (I-84)...	22.99	61000	66100	127100	6
0.40 mile south of Airport Way Interchange...	24.25	50600	54800	105400	6
Glenn Jackson Bridge Automatic Recorder, Sta. 26-024, 1.07 miles south c	25.50	51000	52300	103300	6

Table 4.5 Highway Monthly Traffic Levels (Percentage of annual traffic)

	I-5	I-84	I-205	US 22	US 97
November	7.42	6.01	7.24	7.26	7.11
December	6.83	5.80	6.77	6.72	6.68
January	8.16	7.74	8.24	7.93	7.92
February	8.56	8.03	8.13	8.00	8.06
March	8.03	7.58	8.26	7.60	7.55
April	8.02	6.46	8.58	7.68	7.51

Table 4.6 Passenger Vehicle Factors by Highway

Hwy	**Section**	**Passenger Vehicle %**
I-5	MP 233-251	80
	MP 259-282	85.8
	MP 283-287	90
	MP 289-298	93
I-84	all	75.5
I-205	all	91.3
US 22	all	93.2
US 97	MP 130.19	88.5
	MP 140.03	89.6

The derivation of the factors for passenger vehicles and monthly volumes are provided in Appendix B.

4.3.1.c) Traffic Growth Rates:

The *Traffic Volume Tables* also give traffic growth rates for the preceding 10 years at each permanent counter location. For highway sections older than 10 years, the statewide traffic growth rate was used, as provided in each annual edition of the *Traffic Volume Tables*. Growth factors are listed in Table 4.7.

Table 4.7 Traffic growth rates

Highway	1986-95	1976-85	1966-75
Interstate 5	3.96%	2.62%	4.78%
Interstate 84	5.78%	2.62%	4.78%
Interstate 205	6%	2.62%	4.78%
US Hwy 22	4.61%	2.62%	4.78%
US Hwy 97	4.05%	2.62%	4.78%

4.3.1.d) The Lane Distribution of Traffic:

The distribution of traffic between lanes has an important impact on the pattern of visible studded tire damage. Most severe studded tire rutting shows up on center or left lanes, which are used predominantly by passenger vehicles. Only very general information is available regarding the distribution of traffic in each lane. According to ODOT's Traffic Planning Section, on bi-directional 4-lane highways, 60 percent of traffic tends to travel in the right lane, with the remaining 40 percent in the left lane. On 6-lane bi-directional highways, the left, center, and right lane distribution tends to approximate 14 percent, 56 percent, and 30 percent, respectively. These patterns are highly generalized; it should be apparent from observation that as traffic becomes denser, traffic distribution begins to even out across the lanes.

4.3.2) Issues of Use of the Data:

The above lane distribution figures describe total traffic volume. No data were found regarding the lane distribution of truck traffic for Oregon roads, which should be considerably different from the general traffic flow, since trucks tend to travel predominantly in the right lanes. Coupled with the highly generalized nature of the traffic distribution data, this posed a challenge for isolating the studded tire traffic in a particular lane of a highway. This challenge was resolved in this study by summing the rut depth of each lane for every highway segment, then performing a regression of the combined depth against the total directional studded tire traffic. Since the model assumes a constant wear rate, we represent the equation for the summation of the lanes as a linear combination of the equations for the individual lanes.

In other words, for wear rate, *a*, and studded tire passes, SP,

If

Left lane rut: $Rut^{LEFT} = a * SP^{LEFT}$

And,

Right lane rut: $Rut^{RIGHT} = a * SP^{RIGHT}$

Then

Sum of lanes: $Rut^{LEFT} + Rut^{RIGHT} = a * (SP^{LEFT} + SP^{RIGHT})$

Or,

$Rut^{SUM} = a * SP^{SUM}$

.

A slight inaccuracy of this approach arises for asphalt surfaces. As mentioned earlier, the right lanes of asphalt pavements can be expected to bear some rutting caused by heavy trucks. The summation of lanes includes heavy truck rutting in the rut depth data. This problem was minimized by the exercise of caution during the measurement process, since the distance between studded tire ruts in a lane match the wheel base width of a passenger vehicle. Naturally, the wheel-base for heavy trucks is much wider than that of vehicles.

The Profilometer measurements were taken to correspond to the wheel base width of passenger vehicles. Nevertheless, the possibility of including some truck rutting should be noted, as it would have a positive (increasing) influence on the wear rate estimation. Despite this drawback to summing the data from each lane, in the absence of detailed data regarding the lane distribution of traffic by highway segment, it is clearly the best solution and method.

4.3.3 Studded Tire Use

As described in Chapter 3, a telephone survey of Oregon households was used to determine the level of studded tire use in each of ODOT's five regions. The highest rate is in Region 4, where over 30 percent of vehicles were equipped with studded tires at some time during the 1994-95 winter. Region 3 has the lowest rate; just below 5 percent of vehicles were equipped with studded tires. These rates indicate the number of vehicles using studded tires. Statewide, roughly half of all studded tire users use studded tires on only one axle, and the other half use them on both axles. In Region 4, nearly 60 percent of studded tire vehicles use them on both axles. This *axle* use rate is used in Chapter 5 to estimate the total number of studded tires used.

For the purpose of calculating studded tire traffic, monthly factors were derived from the survey results for each of ODOT's five regions to reflect the changing levels of studded tire use. These are listed in Table 4.8. In two cases, it was determined that highway conditions are better represented by county use rates rather than regional rates. This was the case for

Interstate-84 (Hood River County) and US Highway 97 (Deschutes County). The rationale for this conclusion is described below.

The portion of I-84 represented in the data sets travels through the Columbia River Gorge, between Multnomah and Hood River Counties, which are both included in Region 1. Hood River County, which experiences cooler temperatures than the Willamette Valley, has a much higher use of studded tires than Region 1 as a whole. It was determined for this study that the studded tire use from Hood River County is a better representation of studded tire use on I-84. An analogous situation occurred for Deschutes County in Region 4. Regional and County studded tire use rates are also shown in Table 4.8.

Table 4.8 Regional and County monthly studded tire traffic factors in 1995

	Region 1	Region 2	Region 3	Region 4	Region 5	Hood River	Deschutes
Nov.	8.2%	7.7%	3.5%	24.7%	20.4%	20.0%	27.3%
Dec.	13.3%	10.5%	4.7%	30.0%	25.2%	27.8%	30.8%
Jan.	14.4%	10.7%	4.4%	30.2%	24.5%	28.7%	30.6%
Feb.	14.6%	11.1%	3.9%	29.6%	23.2%	27.8%	30.4%
Mar.	11.3%	9.2%	3.7%	25.5%	18.0%	23.5%	29.1%
Apr.	2.7%	2.0%	1.0%	10.8%	6.5%	8.7%	14.0%
Weighted Ave.	10.7%	8.5%	3.5%	25.1%	19.6%	22.7%	27.0%
Both Axles	45.4%	45.3%	53.7%	59.7%	54.1%	47.0%	69.0%
ST Factor	15.6%	12.4%	5.4%	40.1%	30.2%	33.4%	45.6%

Very little historical data exists regarding studded tire use in Oregon. As was noted earlier, the 1995 OSRL survey indicates that studded tire use doubled over the estimate given in 1974. Estimates from the intermediate years indicate a steady or declining use of studded tires. This would suggest rapid growth during the 1990s.

"Although the methods of gathering data were not consistent, and considerable engineering judgement was exercised in their derivation" (Brunette, 1995),these previous estimates were supported by the telephone survey responses regarding the growth in studded tire use. These responses indicate that the use of studded tires has increased by an average of 8.45% during the six years stretching from 1990 to 1995.

Based on all the information available, it was assumed that the use of studded tires in Oregon was virtually constant from 1967 through 1986, and then increased at an average rate of 8.45 percent annually.[2]

4.4 Regression Analysis

Studded tire passes over the life of the pavement were calculated for the highway segments of the main data set. These data represent the sum of studded tire traffic and rut depth in all lanes. The test data set (manual measurements) was also used.

Linear regressions were run on both the main and the test data sets. The data were grouped by surface type: asphalt (F-mix and B-mix) and PCC. The estimates are corrected for autocorrelation that results from the interdependence of traffic volumes on adjacent road sections. Wear rates were estimated for every 100,000 studded tire passes. The results of the regression analyses are shown in Tables 4.9[3.] Along with individual wear rate estimates,

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2 Additional analysis was conducted using a constant growth rate in studded tire use with no significant difference in wear rate estimates.

3 R^2 values are not given. In cases of regressions through the origin, the R^2 measures variation around zero, rather than around the mean. It has been argued that for regression through the origin, R^2 can lead to over estimation of the adequacy of fit of the model. Standard error is a better tool for evaluating the regression results (Casella, 1983; Hahn, 1977).

averages and midpoints for each surface type are listed. Midpoints are used to represent the base case in the remaining analyses. Full regression results are provided in Appendix C.

Eight wear rate estimates were determined for PCC surfaces; 13 for asphalt surfaces. For each surface type, a range of wear rates was estimated. This should be expected due to the many factors affecting rutting susceptibility of pavements.

Table 4.9 a Estimated Wear Rates (per 100,000 studded tire passes) for F-Mix asphalt

Data Set	Location	Wear rate	Std Err	T-stat	95% Conf. Interval		DF
Main	5 South, MP 234-247	0.0438	0.0021	21	0.0432	0.0444	52
Main	5 South, MP 294-299	0.0256	0.0012	21	0.0251	0.0261	22
Main	84 E&W, MP 22-31	0.0326	0.0034	9.6	0.0319	0.0333	85
Manual	I5 South, MP 245	0.0393	0.0009	44	0.0391	0.0395	80
Manual	I5 South, MP 243	0.0406	0.0006	67	0.0405	0.0407	81
Manual	US 97, MP 133.5	0.0517	0.0022	23	0.0512	0.0522	80
Manual	US 97, MP 140.4	0.0397	0.0012	34	0.0394	0.0400	80
	Range	0.0256 : 0.0517					
	Average	0.0390					
	Mid-Point	0.0387					

As indicated by comparison of mid-points, no clear performance advantage was found between F-mix and B-mix asphalt pavements; the mid-points were very close for both mixes (0.0387 and 0.0385, respectively). Estimates from the manual measurements on I-5 are also similar, at around 0.040 inch. Due to the close physical proximity of the samples (from mileposts (MP) 242.75 to MP 245), we can expect that general conditions (traffic volumes, climate, etc.) are quite similar. However, estimates from the main data set indicate better performance by B-mix surfaces. Other recent studies indicate no consistent advantage of B-mix over F-mix in terms of rutting (Brunette, 1995; Hicks, 1995).

Table 4.9 b Estimated Wear Rates (per 100,000 studded tire passes) for B-Mix asphalt

Data Set	Location	Wear rate	Std Err	T-stat	95% Conf. Interval		DF
Main	5 North, MP 234-244	0.0299	0.0012	25	0.0295	0.0303	46
Main	5 North, MP 244-249	0.0196	0.0013	15	0.0191	0.0201	24
Main	84 E&W, MP 17-22	0.0349	0.003	25	0.0340	0.0358	47
Manual	I5 North, MP 242.75	0.0399	0.005	8	0.0388	0.0410	76
Manual	22, Test set (EB)	0.0573	0.002	35	0.0569	0.0577	80
Manual	84 East, MP 20	0.0358	0.002	23	0.0354	0.0362	80
	Range	0.0196 : 0.0573					
	Average	0.0362					
	Mid-Point	0.0385					

As was expected, PCC was found to have a considerably lower wear rate than asphalt. PCC has consistently shown more resistance to rutting than asphalt (Minnesota, 1971; Christman, 1978; Krukar, 1973).

Table 4.9 c Estimated Wear Rates (per 100,000 studded tire passes) for PCC

Data Set	Location	Wear rate	Std Err	T-stat	95% Conf. Interval		DF
Main	5 North, MP 259-280	0.0110	0.0002	56	0.0110	0.0110	100
Main	5 South, MP 259-294	0.0076	0.0005	15	0.0075	0.0077	169
Main	205 North, MP 0-25	0.0086	0.0003	33	0.0085	0.0087	118
Main	205 South, MP 0-25	0.0084	0.0002	40	0.0084	0.0084	123
Manual	I5 North, MP 262	0.0100	0.0001	96	0.0100	0.0100	80
Manual	I5 North, MP 278	0.0097	0.0002	61	0.0097	0.0097	80
Manual	I5 South, MP 287.5	0.0077	0.0001	81	0.0077	0.0077	80
Manual	205 MP 12 (NB)	0.0083	0.0002	48	0.0083	0.0083	80
	Range	0.0076 : 0.0110					
	Average	0.0089					
	Mid-Point	0.0093					

4.5 Other Rut Estimates

Table 4.10 shows wear rate estimates from other studies. The base case estimates from the present study appear similar to other recent studies from Oregon (Malik, 1994; Brunette, 1995), which both used 1993 data. The 1974 ODOT study found a much higher wear rate, suggesting that a sharp decline in the wear rate of studded tires has taken place in the last two decades. This is probably a reflection of design changes that occurred after the 1970s. During that period, tire stud manufacturers improved designs in response to calls for a prohibition of studded tire use (Brunette, 1995).

Wear rates can be expected to decline in the future as a result of recent legislation restricting the sale of studs in Oregon to those made of lightweight material. Lightweight studs have been found to reduce wear by 30-50 percent (Barter, 1996; Gustafson, 1992). ODOT pavement engineers, who are working to develop pavements that are less susceptible to rutting, may realize a further reduction in wear from their current research.

Table 4.10 Estimated wear rates from other studies (per 100,000 studded tire passes)

State	Source	Asphalt	PCC
Oregon	ODOT, 1974	0.066”	0.026”
Oregon	Malik, 1994	0.035”	0.008”
Oregon	Brunette, 1995	0.034”	0.009”
Alaska	Barter, 1996	0.013”	
Minnesota	MDOT, 1971	0.030”-0.047”	0.075”-0.091”
Wisconsin	Lyford, 1977	0.015”-0.020”	0.007”-0.010”

Chapter 5

Cost Estimates

Three types of cost analyses were conducted using wear rate estimates and studded tire and traffic data for the state highway system in 1995. All cost estimates are expressed in terms of repair costs. Those repair costs are limited to a rehabilitation strategy of an asphalt overlay of 2” thickness.

The first cost category is the cost of *total damage*. This estimate is a measure of all the rutting damage on the highways. This includes rutting damage that is not expected to reach the limiting rut threshold of 0.75”. It also includes damage that might not be the main trigger for pavement rehabilitation. Although some of the expenditures are not anticipated, damage has occurred. Therefore, this damage will not require repair in total, but it represents the cost of mitigation if all the damage were to be fixed, regardless of how deep the rutting gets on any particular highway segment. There is no inclusion in this category of the consequent social costs in terms of safety and comfort effects (discussed in section 2.1). The use of repair costs can not be utilized to quantify these indirect effects, and does not provide means of measuring the accelerated wear (beyond Rutting damage) of roadways due to studded tire use.

The second cost category is the *effective damage* cost. The *effective damage* cost estimate includes studded tire damage that is expected to reduce the useful life of pavement surfaces. Roads with very low traffic volume or very low studded tire use may exhibit some rutting, but the studded tire traffic is not considered sufficient to require an overlay before other age and pavement fatigue-related problems warrant reconstruction. Therefore, this cost category concentrates on the damage that will require mitigation expenditures in the future, and annualizes this expenditure to the current year.

The final type of estimate is the A*nnual or Cashflow expenditures* on pavement repair of studded tire damage. Damage mitigation is projected by the year of failure of the pavement. The horizon for this category is projected for the years 1995-2005. The projections are then adjusted for possible reductions in the damage as a result of the introduction of lightweight studs.

Assumptions

The three cost analyses utilize some common assumptions:

- Limiting rut threshold: Pavements require resurfacing when the studded tire rut depth reaches 0.75".
- Design life: Pavements require reconstruction when they reach the end of their design life. This is the expected useful life in the absence of studded tire traffic.
- Studded tire use, seasonal traffic level, and the passenger vehicle percentage of traffic are factored in by region.
- No distinction is made between types of asphalt surfaces. Wear rates used for asphalt are the averages of open-graded and dense-graded mixes.

- Repair costs: The assumed method of repair is a 2" asphalt overlay, and lane width is assumed to be 12'. The overall cost is $52,800/lane mile, which covers material costs and the agency costs of temporary traffic control, in addition to labor and other costs. Cost estimates were taken from "*Repair of Rutting Caused by Studded Tires*", ODOT, July-95 by Hoffman and Hunt.
- Due to the nature and plasticity of each pavement, the required repairs will be different. On asphalt surfaces, only the damaged lane(s) need to be overlaid. Conversely, if a single lane of a PCC highway reaches the threshold rut, the entire width of the highway, including the shoulders, needs to be repaired. The shoulders are assumed to be 6' and 10' wide, which is equivalent to adding 1.33 lanes.

Table 5.1 shows the range of wear rates used in the analyses. The mid-point wear rate is considered the Base case. Table 5.2 shows the range of design life values used. Additional assumptions are made for the effective damage estimates and expenditure projections:

Table 5.1 Wear rates used in cost analyses

	Asphalt	PCC
LOW	.0226	.0076
BASE	.0386	.0093
HIGH	.0545	.0110

Table 5.2 Design life values used in cost analysis

	Asphalt	PCC
LOW	12	25
BASE	14	30
HIGH	16	35

- Lane distribution of total traffic[1]: The traffic distribution information from ODOT's Traffic Planning Section was used for general traffic.
- Lane distribution of truck traffic: In order to isolate passenger vehicle traffic from heavy truck traffic, an assumption was made that 95 percent of trucks travel in the right lane and the remaining trucks travel in the adjacent lane. Lane distribution factors for total traffic and for heavy trucks are given in Table 5.3.
- All vehicles are either trucks or passenger vehicles.

Table 5.3 Lane Split Factors for Total Traffic and Trucks

	Two Lanes		Three Lanes		
	left	right	left	center	right
Total Traffic	40%	60%	16%	54%	30%
Truck Traffic	5%	95%	0%	5%	95%

[1] Unlike the estimation procedures for wear rate and total damage, it is necessary to assign rutting to a particular lane for the effective damage and expenditure projections. In the previous estimations, an assumption of linear dependence was made. However, the cost calculation is not a continuous function, but rather a discrete event: when the rut depth reaches 0.75", an expense occurs. It was necessary to utilize the "best" available information on lane split of traffic, and to make an additional assumption for the lane split of trucks.

5.1 Total Damage Cost Estimate

The Total Damage cost model effectively "accumulates" all the rut depth into sections that are 0.75" deep, then calculates the cost for an equivalent number of lane-miles. For example, a three-mile lane section with 0.5" rut depth is equivalent to 2 miles with 0.75". The damage cost is then calculated for the two miles of asphalt overlay.

5.1.1 Total Damage Estimation Methodology

The total damage cost estimation procedure does not require linking studded tire traffic to any particular highway segment because all rutting is accumulated to meet the threshold. Overall traffic volume can be used rather than highway traffic data. Vehicle Miles Traveled (VMT[2]) data were provided by ODOT's Transportation Data Section. These data were broken down by region and surface type (asphalt and concrete). This data on regional VMT by pavement type are shown in Table 5.4.

Table 5.4

1995 VMT Totals				
REGION	**Asphalt**	**PCC**	**Other**	**TOTALS**
1	4,561,505,375	1,882,204,990	-	6,443,710,365
2	4,461,653,055	1,099,305,540	106,215	5,561,064,810
3	2,329,388,390	490,393,560	719,780	2,820,501,730
4	1,931,755,930	26,615,800	444,205	1,958,815,935
5	1,337,809,315	232,164,455	74,825	1,570,048,595
TOTALS	14,622,112,065	3,730,684,345	1,345,025	18,354,141,435

[2] VMT = a measure of total miles traveled by all vehicles in the area for a specified time period.

Applying regional factors for passenger vehicles (Table 5.5), seasonal traffic volume and studded tire use, an estimate for Studded Tire VMT was generated for the year 1995. Then the estimated wear rate, a, was applied for each surface type using the relationship:

$$Rut_{95} = a * VMT_{95}$$

Table 5.5

REGIONAL SUMMARIES

	Passenger Vehicles	Seasonal Factor	Effective Stud Use
Region 1	88%	44%	15.6%
Region 2	85%	45%	12.4%
Region 3	84%	43%	5.4%
Region 4	81%	43%	40.1%
Region 5	78%	41%	30.2%

The following steps were taken for both surface types in each region:

Step 1. Studded tire VMT * wear rate = Total rut

Step 2. The resulting number is equivalent to total rut depth. Since repair is assumed to take place when rut depth reaches a threshold of 0.75”, dividing by 0.75 yields the equivalent number of lane miles at the threshold.

Step 3. $$\frac{\text{Total LnMil rut}}{0.75''} = \text{Total LnMi at Threshold}$$

Step 4. Multiply Total Lane Miles at Threshold by the cost of repair per lane mile

Total Mitigation Cost = Total LnMi at threshold * cost LnMi

5.1.2 Total Damage Cost Results

The model estimates that 1995 total studded tire traffic, using the base wear rate, produced damage equivalent to 0.75" rut depth on 18.74 lane miles of PCC and 360 lane miles of asphalt on the state highway system alone. The associated cost of repairing this level of damage is more than $30 million, with more than 80 percent of the costs for asphalt surfaces.

Table 5.6

Summary of total cost of mitigating studded tire damage.

Estimate	Pavement	State	Local	Total
	PCC	$4,313,193	$0	$4,313,193
	Asphalt	$14,821,972	$11,526,412	$26,348,384
Low estimate		**$19,135,165**	**$11,526,412**	**$30,661,577**
	PCC	$5,277,987	$0	$5,277,987
	Asphalt	$25,315,403	$19,686,704	$45,002,107
Base estimate		**$30,593,390**	**$19,686,704**	**$50,280,093**
	PCC	$6,242,780	$0	$6,242,780
	Asphalt	$35,743,250	$27,795,993	$63,539,244
High estimate		**$41,986,030**	**$27,795,993**	**$69,782,024**

VMT for county and city roads were assumed 39 percent of the total state VMT. Based on this assumption, the model estimates just under $20 million for county and city roads studded tire damage in 1995.

Cost summaries for all three of wear rates are provided in Table 5.6. The full detail printout for the Base wear rate is shown in Figure 5.1. The low and high wear rate estimates are provided in Appendix D.

Figure 5.1

STUDDED TIRE PAVEMENT DAMAGE ESTIMATE FOR 1995

		State System							County & City	
REGION	PAVEMENT TYPE	1995 GROSS VMT	ANNUAL GROWTH	% LT VEH	SEASONAL FACTOR	% STUD USE	VMT Season	IN/LN/MI DAMAGE	Vmt 39% of total	IN/LN/MI DAMAGE
1	CONCRETE	1,882,204,990	1.30%	88%	44%	15.6%	113,691,204	10.67	-	0.00
1	ASPHALT	4,561,505,375	1.30%	88%	44%	15.6%	275,529,521	106.35	248,846,038	96.05
2	CONCRETE	1,099,305,540	1.30%	85%	45%	12.4%	52,140,062	4.85	-	0.00
2	ASPHALT	4,461,659,056	1.30%	85%	45%	12.4%	211,616,204	81.68	168,631,055	65.09
3	CONCRETE	490,393,560	1.30%	84%	43%	5.4%	9,565,028	0.89	-	0.00
3	ASPHALT	2,329,388,390	1.30%	84%	43%	5.4%	45,434,255	17.54	35,163,476	13.57
4	CONCRETE	26,615,800	1.30%	81%	43%	40.1%	3,717,384	0.35	-	0.00
4	ASPHALT	1,931,755,930	1.30%	81%	43%	40.1%	269,805,067	104.14	174,875,009	67.50
5	CONCRETE	282,164,455	1.30%	78%	41%	30.2%	22,422,350	2.09	-	0.00
5	ASPHALT	1,397,809,315	1.30%	78%	41%	30.2%	129,205,089	49.87	96,942,193	37.42

		CONCRETE	0.093					
		ASPHALT	0.386					
DAMAGE FACTORS	PER MILLION VMT		0.386	INCH/LANE/MILES DAMAGES	CONCRETE	18.74	CONCRETE	0.00
			0.386		ASPHALT	359.59	ASPHALT	279.64
			0.386					

	MITIGATING STRATEGY	REPLACE COST LN/MI	THRESHOLD (INCHES)		COST		COST
ANNUAL DAMAGE	2" AC OVERLAY (PCC)	$211,200	0.75	CONCRETE	$5,277,987	CONCRETE	$0
	2" AC OVERLAY	$52,800	0.75	ASPHALT	$25,315,403	ASPHALT	$19,686,704
					$30,593,390		$19,686,704

	TOTAL COST
CONCRETE	5,277,987
ASPHALT	45,002,107
TOTAL COST	$ 50,280,093

Base

5.2 Effective Damage Cost Estimate

The *effective damage* cost estimate includes studded tire damage that is expected to reduce the useful life of pavement surfaces. Costs are assigned to the year in which the damage is incurred on an annualized basis, rather than linked to the year that the expenditure is made.

5.2.1 Effective Damage Estimation Methodology

The effective damage cost analysis utilizes a database provided by ODOT's Pavement Management Section. The pavement database divides the state highway system into roughly 2,200 highway segments of various lengths. Beginning and ending mileposts designate each segment. Data provided include directional traffic (ADT) and surface type. For each segment, only one ADT value is provided. No distinction is made between F-mix and B-mix asphalt surfaces in the database. The low, mid-point, and high wear rates for both mixes are averaged for the cost analysis.

Unlike the wear rate estimation, the cost analysis requires isolating rutting to each particular lane. Total traffic is determined for each lane of highway. Studded tire traffic is then calculated using the regional factors for seasonal traffic and studded tire use. The derivations of regional factors for passenger vehicles and seasonal traffic volumes are shown in Appendix E.

The following steps are taken for each highway section in the pavement database:

Step 1: Split ADT by lane using lane distribution factors for total traffic to determine Lane Average Daily Traffic (LADT):

$LADT = ADT * L_{x.y}\%$

where, $LADT_x$ = Average daily traffic for 1995 in lane x,

ADT = Average Daily Traffic for 1995,

$L_{x,y}$ = Lane factor for the x lane (Left, Center, Right) on a y- (two or three) lane highway

Step 2: Adjust lane traffic to isolate passenger vehicle Lane ADT (PvLADT) using the assumed lane distribution of truck traffic.

$PvLADT_x = LADT_x - T_x (1 - PV_k)$,

Where, PV_k = fraction of passenger vehicle traffic in Region k, and

T_x = fraction of truck traffic in lane x.

Step 3: Apply regional factors for seasonal volume and studded tire use to calculate 1995 studded tire traffic:

$SP_x = PvLADT_x * 365 * S_k\% * ST_k\%$

Step 4: Apply the appropriate wear rate, *a*, for each surface to calculate the rut depth attributable to 1995 traffic:

$R_x = SP_x * a$

Where, R_x = the estimated average rut depth along the entire lane x

Step 5: Calculate the Expected Life (EL), the expected number of years until the pavement reaches the threshold rut depth of 0.75”:

$EL_x = 0.75''/R_x$

Where,

ELx = the Expected Life of lane x of the pavement section

Step 6: Determine whether studded tire traffic will reduce the pavement life:

If the Expected Life is less than the Design Life (DL) for the surface type, then the studded tire traffic is considered sufficient to reduce the useful life of the pavement.

For asphalt, a cost is calculated if the following criterion is met:

If $EL_x < DL$,

Then a cost is charged.

Recall that when any lane of a PCC surface highway requires an overlay, the entire width of the road, as well as the shoulders, must be overlaid. A cost is charged for PCC surfaces when the following conditional criterion is met:

$(EL_L \text{ or } EL_C \text{ or } EL_{R.}) < DL$,

Where,

EL_L = EL for the left lane,

EL_C = EL for the center lane,

EL_R = EL for the right lane,

Step 7. Cost calculation:

The cost of an asphalt overlay attributed to 1995 ($cost^{95}$) is based on an even distribution of the overlay cost among the years of useful life of the pavement:

For Asphalt,

Total Cost = $52,800*LnMi

$Cost^{95}$ = Total Cost ÷ EL_x

For PCC,

Total Cost = $52,800*LnMi*(Lanes + 1.333)

$Cost^{95}$ = Total Cost ÷ EL

Where,

Lanes = the number of lanes, and

1.333 = the lane equivalent of adding both shoulders.

5.2.2 Effective Damage Cost Results

The cost estimates do not necessarily represent expenditures made during 1995, but rather damage incurred during 1995. A summary of the costs for the base wear rate and design life is provided in Table 5.7. Cost estimates for all of the nine scenarios are summarized in Table 5.8, with details provided in Appendix F.

Table 5.7 Summary of effective cost estimates, Base case.*

	PCC	Asphalt	Total
Region 1	$2,121,389	$3,019,116	**$5,140,505**
Region 2	$741,829	$1,810,814	**$2,552,643**
Region 3	$0	$0	**$0**
Region 4	$0	$2,242,845	**$2,242,845**
Region 5	$0	$129,238	**$129,238**
Statewide	**$2,863,218**	**$7,202,013**	**$10,065,231**

* Asphalt design life and wear rate: 14 years, 0.0386”.
PCC design life and wear rate: 30 years, 0.0093”.

The results indicate the cost of effective damage from studded tires, in the base case scenario, was over $10 million in 1995 for the state highway system. Although this is very close to the maintenance expenditure amount ($11 million) attributed to studded tire damage by ODOT’s updated *Cost Responsibility Study* (1995), it is important to remember that the present $10 million estimate reflects studded tire damage inflicted during 1995, whereas ODOT’s $11 million dollar figure reflects mitigation expenditures during the year on the State Highway System as well as City streets and County roads.

The nine scenarios result in cost estimates ranging from $3.7 million to $18.3 million, depending on the wear rate and the design life values used. Holding the wear rate at the base level, the different design life values result in a range of costs from roughly $9 million to $11 million. The design life, as used in this study, is basically the expected useful life of a pavement surface in the absence of studded tires. A shorter design life lowers the cost estimate because it lowers the relative impact of studded tire damage on the useful life. The actual useful life of a pavement is influenced by many factors, such as construction design, aggregate type and size, other materials, climate and traffic conditions. Furthermore, the determination of a useful life is by no means uniform in all cases. Some differences of opinion exist regarding the level of damage when a pavement absolutely requires repair or reconstruction. The base case values

Table 5.8

Design life	Wear rate	Asphalt	PCC	Total Cost
Short	Low	$1,473,153	$2,256,597	$3,729,750
Base	Low	$1,901,186	$2,339,834	$4,241,020
Long	Low	$2,628,995	$2,339,834	$4,968,829
Short	Base	$6,134,818	$2,863,218	$8,998,036
Base	Base	$7,202,013	$2,863,218	$10,065,231
Long	Base	$8,162,295	$2,863,218	$11,025,513
Short	High	$12,334,399	$3,386,602	$15,721,001
Base	High	$13,891,958	$3,386,602	$17,278,560
Long	High	$14,861,168	$3,466,596	$18,327,764

used here are considered "typical" for Oregon (Hoffman, 1995).

A wider range results from varying the wear rate. It is important to recall that the range of wear rate estimates reflects variability in actual wear rates, not confidence limits of the estimate. Therefore, it is unlikely that either the low or the high wear rate can be considered representative for the entire state highway system, and that the very low or very high cost estimates reflect actual pavement damage from 1995.

The low wear rate does provide some indication of the possible cost impact of the lightweight stud mandate, which is expected to reduce the rutting for each tire by 30 to 50 percent (Barter, 1996). The actual reduction on the highways will happen over time, as conventional studded tires purchased in previous years are replaced with new lightweight studded tires. In addition, there may always be some users who will bring conventional studs from neighboring states. New asphalt mix designs, currently under study by ODOT pavement engineers, may further reduce wear. Therefore, the low wear rate estimates may be considered a reasonable representation of pavement damage in future years.

More than 70 percent of the cost is for asphalt surfaces, which is by far the predominant surface type in Oregon. Over half of the costs occur in Region 1. That is not unusual due to the high volume interstate highways located in Region 1, and the high proportion of PCC surface roads. PCC surface roads are costly to overlay because all lanes must be resurfaced if any lane is resurfaced. These characteristics are present in Region 2 to a lesser degree, where 25 percent of costs occur. Approximately 22 percent of the costs are attributed to asphalt in Region 4, which has relatively low volumes but high studded tire use. Region 3, with very low studded tire use and traffic volumes, accounts for none of the effective damage cost. The small costs seen for Region 5 are due to low volumes of traffic. Since Region 5 does not have many PCC pavements, all the costs are incurred on the asphalt pavements.

5.3 Projected Expenditures for Mitigating Studded Tire Damage

The expenditure projections utilize the same pavement database that was used in the effective damage cost estimation. Historical growth factors for studded tire use and traffic volume were used to calculate the total studded tire traffic over the life of each pavement section. Application of the wear rate estimates produced an estimate of accumulated rut depth as of 1995. Then, using forecasted growth rates, cumulative rut depth was estimated for each year through 2005.

The model assumes there are two possible reasons that a road section will require some rehabilitative action. First, if the pavement age reaches its design life, the entire road section is reconstructed due to deterioration other than studded tire damage. No cost is charged to studded tire use. Second, if the pavement has not yet reached its design life, and its rut depth due to studded tire traffic reaches 0.75”, then an asphalt overly is required. In these cases, the entire cost of the overlay is charged to studded tire use.

In either case, the surface in the following year is assumed to be brand new, with no accumulated rutting. When PCC surfaces are overlaid, the surface becomes asphalt until the original design life dictates that reconstruction takes place. The decision processes for PCC and asphalt are illustrated in the flow charts in Figure 5.2 and 5.3.

5.3.1 Methodology

Step 1. As in the methodology for the effective damage cost estimation, calculate studded tire traffic for each lane for 1995.

Step 2. Calculate the lifetime studded tire traffic using effective growth figures and the equations in the manner specified in Section 4.3

Step 3. Apply wear rates to estimate the total rut depth accumulated as of 1995.

Total Rut = $Sp^{life} * a$

Step 4. Determine action: Determine whether reconstruction (due to age) or asphalt overlay (due to rutting) or no action is needed. Apply cost for overlays; no cost is charged for reconstruction. In both cases, the pavement age is adjusted to 1 year in 1996.

Step 5. 1996 (and subsequent years): apply forecasted growth rate for traffic and studded tire use to estimate the studded tire traffic for 1996. Apply wear rate and add to last year's cumulative rut. If the surface age is 1 year, last year's rut was 0.

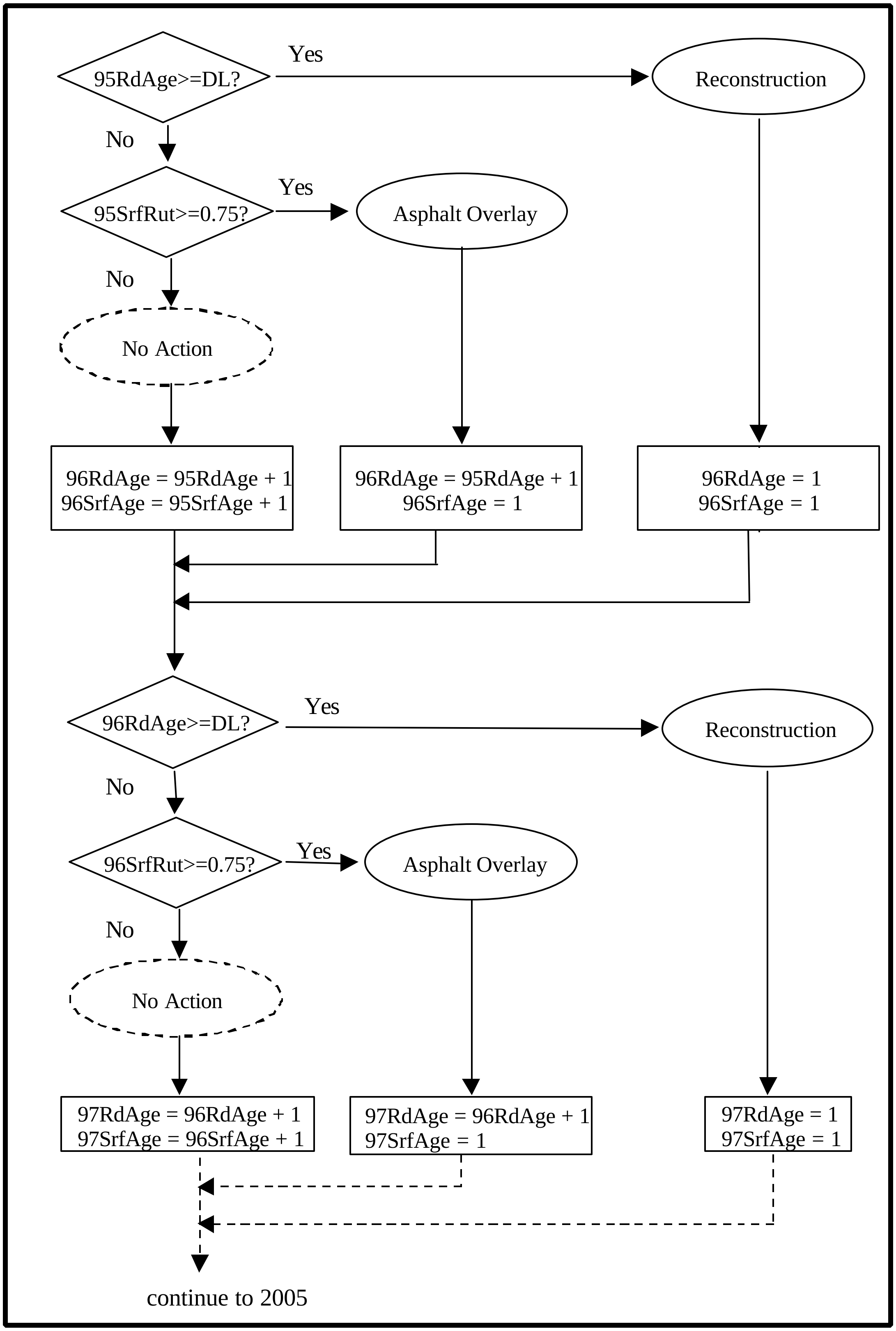


Figure 5.2 Decision process for determining road and surface age on asphalt surfaces

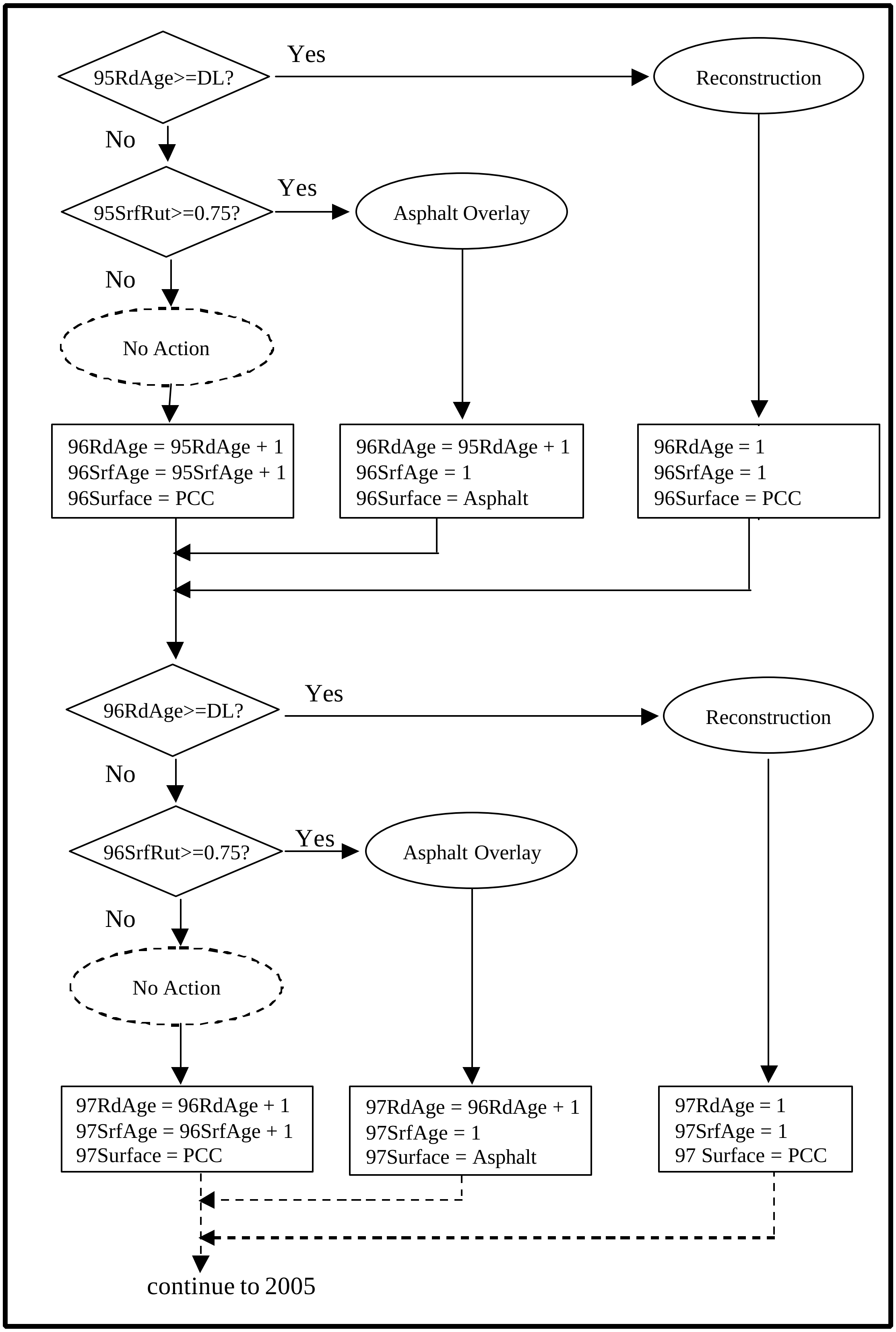


Figure 5.3 Decision process for determining road and surface age on PCC surfaces

5.3.2 Estimates of Projected Expenditures for Mitigation of Studded Tire Damage

Summaries of expenditures projected under the Base scenario are shown in Figures 5.4-a, b, and c. The three wear rates and the base design life of 14 years for asphalt, and 30 years for PCC are considered. The nine scenarios that estimate all of the possibilities for wear rates and pavement design life are given in Table 5.8. Detailed print-outs are shown in Appendix G. The Base Case model (Base wear rate and Base design life) estimates that total expenditures for repairing studded tire damage will be just above $100 million for the 11 years spanning 1995 to 2005.

Figure 5.5a charts the expenditures of the Base design life (14 and 30 years), with varying wear rates. Likewise, Figures 5.5b and 5.5c chart expenditures using the longer design life, and wear rate values. In each case, an upward trend is apparent.

It is important to mention that this model is able to predict which highway segment will reach the threshold in which year. The rut depth reached at a certain year will trigger a required rehabilitation. Therefore, it could have a side benefit of forecasting which highway segments will be in need of repair in the near future.

Figure 5.4-a

BASE

Expenditure Projections for Repair of Studded Tire Damage

Assuming reconstruction when pavement reaches design life

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	1,043,856	280,368	0	0	0	**1,324,224**
1996	119,856	821,040	0	0	0	**940,896**
1997	591,888	476,784	0	350,064	0	**1,418,736**
1998	1,999,008	505,824	0	792,000	0	**3,296,832**
1999	3,352,272	1,207,008	0	281,424	0	**4,840,704**
2000	1,726,032	907,632	0	1,723,392	0	**4,357,056**
2001	3,602,016	1,324,752	0	1,094,016	10,560	**6,031,344**
2002	2,346,432	993,696	0	3,798,432	164,208	**7,302,768**
2003	5,295,312	2,004,288	0	4,533,936	186,384	**12,019,920**
2004	4,100,976	4,208,160	0	4,301,616	0	**12,610,752**
2005	3,489,552	3,544,992	0	3,049,728	364,848	**10,449,120**
11-year	**27,667,200**	**16,274,544**	**0**	**19,924,608**	**726,000**	**$ 64,592,352**

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	4,074,615	0	0	0	0	**4,074,615**
1996	3,289,891	0	0	0	0	**3,289,891**
1997	3,134,319	0	0	0	0	**3,134,319**
1998	876,480	0	0	0	0	**876,480**
1999	1,157,904	0	0	0	0	**1,157,904**
2000	5,664,195	6,039,855	0	0	0	**11,704,050**
2001	680,592	4,742,659	0	0	0	**5,423,251**
2002	3,797,558	0	0	0	0	**3,797,558**
2003	1,069,200	0	0	0	0	**1,069,200**
2004	3,121,359	0	0	0	0	**3,121,359**
2005	832,656	0	0	0	0	**832,656**
11-year	**27,698,768**	**10,782,515**	**0**	**0**	**0**	**$ 38,481,282**

Variable Surface Inputs

	AC	PCC
Design Life	14	30
Wear Rate	0.0386	0.0093

Studded tire growth

1996-2005	2.50%
1986-1995	8.45%
1976-1985	0.00%
1968-1975	0.00%

AC and PCC Total

Projected Repair Totals

1995	**$ 5,398,839**
1996	**$ 4,230,787**
1997	**$ 4,553,055**
1998	**$ 4,173,312**
1999	**$ 5,998,608**
2000	**$ 16,061,106**
2001	**$ 11,454,595**
2002	**$ 11,100,326**
2003	**$ 13,089,120**
2004	**$ 15,732,111**
2005	**$ 11,281,776**
total	**$ 103,073,634**

Figure 5.4-b

LOW

Expenditure Projections for Repair of Studded Tire Damage

Assuming reconstruction when pavement reaches design life

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	29,568	0	0	0	0	**29,568**
1996	77,088	0	0	0	0	**77,088**
1997	805,728	0	0	0	0	**805,728**
1998	34,848	147,312	0	0	0	**182,160**
1999	390,720	147,312	0	75,504	0	**613,536**
2000	1,309,968	312,048	0	538,560	0	**2,160,576**
2001	2,568,720	670,560	0	369,600	0	**3,608,880**
2002	1,334,784	524,832	0	7,392	0	**1,867,008**
2003	668,448	594,000	0	63,888	0	**1,326,336**
2004	2,438,304	1,171,104	0	1,147,872	0	**4,757,280**
2005	1,128,336	396,528	0	288,816	10,560	**1,824,240**
11-year	**10,786,512**	**3,963,696**	**0**	**2,491,632**	**10,560**	**$ 17,252,400**

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	1,647,233	0	0	0	0	**1,647,233**
1996	1,633,506	0	0	0	0	**1,633,506**
1997	0	0	0	0	0	**0**
1998	3,289,891	0	0	0	0	**3,289,891**
1999	3,329,165	0	0	0	0	**3,329,165**
2000	399,682	0	0	0	0	**399,682**
2001	281,952	0	0	0	0	**281,952**
2002	5,805,699	0	0	0	0	**5,805,699**
2003	0	0	0	0	0	**0**
2004	2,496,566	0	0	0	0	**2,496,566**
2005	1,659,054	0	0	0	0	**1,659,054**
11-year	**20,542,748**	**0**	**0**	**0**	**0**	**$ 20,542,748**

Variable Surface Inputs

	AC	PCC
Design Life	14	30
Wear Rate	0.0226	0.0076

Studded tire growth

1996-2005	2.50%
1986-1995	8.45%
1976-1985	0.00%
1968-1975	0.00%

AC and PCC Total

Projected Repair Totals

1995	**$ 1,676,801**
1996	**$ 1,710,594**
1997	**$ 805,728**
1998	**$ 3,472,051**
1999	**$ 3,942,701**
2000	**$ 2,560,258**
2001	**$ 3,890,832**
2002	**$ 7,672,707**
2003	**$ 1,326,336**
2004	**$ 7,253,846**
2005	**$ 3,483,294**
total	**$ 37,795,148**

Figure 5.4-c

HIGH

Expenditure Projections for Repair of Studded Tire Damage

Assuming reconstruction when pavement reaches design life

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	1,155,264	1,872,816	0	0	0	**3,028,080**
1996	496,320	898,656	0	707,520	0	**2,102,496**
1997	2,521,728	1,816,320	0	1,826,352	0	**6,164,400**
1998	3,338,016	882,816	0	1,418,208	602,448	**6,241,488**
1999	5,013,888	877,008	0	1,556,016	10,560	**7,457,472**
2000	2,801,568	2,091,936	0	3,674,880	270,864	**8,839,248**
2001	6,408,336	2,733,456	0	7,582,080	79,728	**16,803,600**
2002	6,588,912	5,284,224	0	8,403,648	0	**20,276,784**
2003	6,849,744	5,052,432	0	8,690,352	364,848	**20,957,376**
2004	5,102,064	2,306,304	163,152	4,434,672	649,968	**12,656,160**
2005	6,809,088	4,179,648	0	6,904,128	1,730,784	**19,623,648**
11-year	**47,084,928**	**27,995,616**	**163,152**	**45,197,856**	**3,709,200**	**$ 124,150,752**

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	7,549,819	0	0	0	0	**7,549,819**
1996	2,949,005	0	0	0	0	**2,949,005**
1997	1,516,416	0	0	0	0	**1,516,416**
1998	5,778,529	6,453,952	0	0	0	**12,232,480**
1999	2,884,346	4,328,563	0	0	0	**7,212,909**
2000	2,124,093	0	0	0	0	**2,124,093**
2001	3,326,632	1,489,488	0	0	0	**4,816,120**
2002	1,617,264	998,976	0	0	0	**2,616,240**
2003	3,448,719	0	0	0	0	**3,448,719**
2004	1,856,448	0	0	0	0	**1,856,448**
2005	4,237,789	0	0	0	0	**4,237,789**
11-year	**37,289,060**	**13,270,979**	**0**	**0**	**0**	**$ 50,560,039**

Variable Surface Inputs

	AC	PCC
Design Life	14	30
Wear Rate	0.0545	0.011

Studded tire growth

1996-2005	2.50%
1986-1995	8.45%
1976-1985	0.00%
1968-1975	0.00%

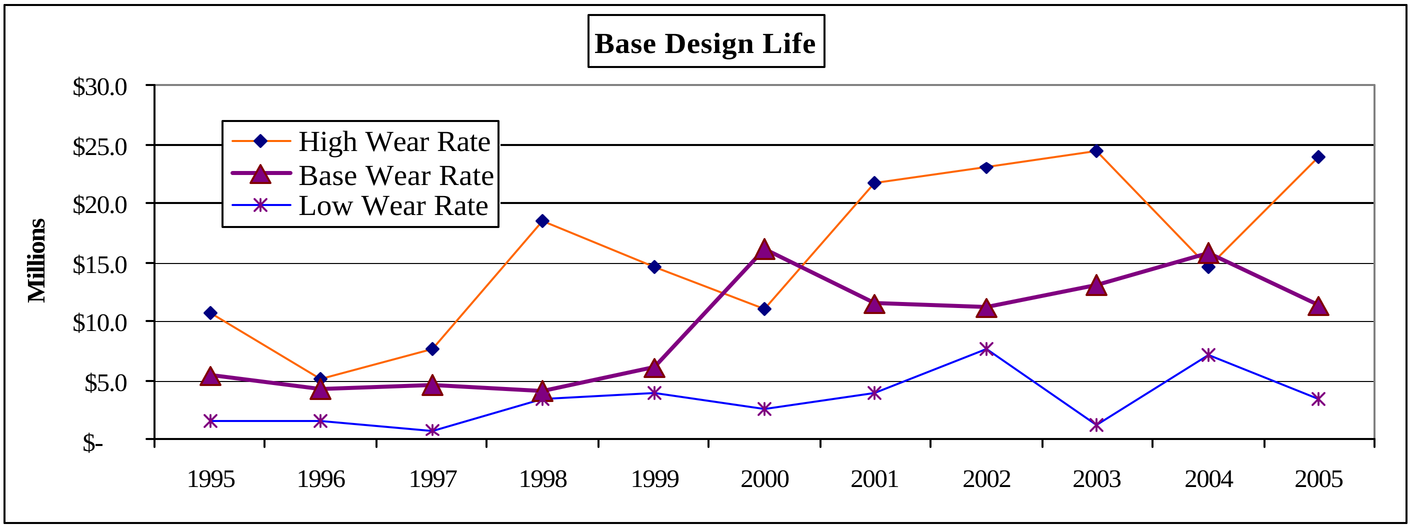
AC and PCC Total

Projected Repair Totals

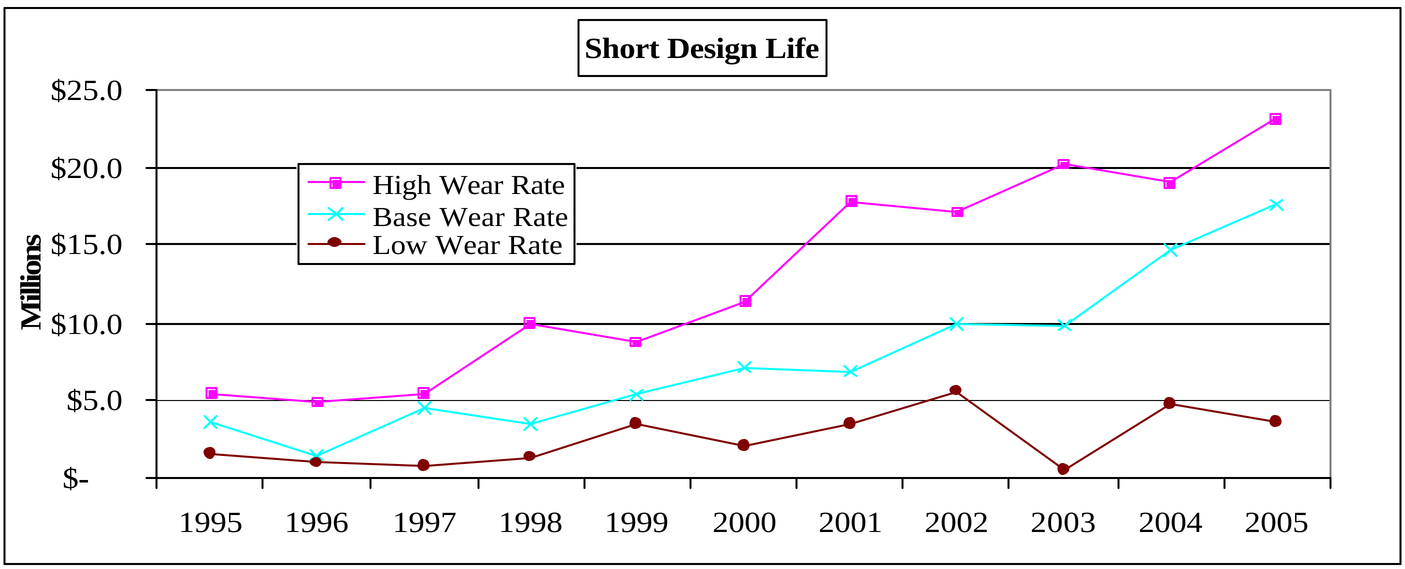
1995	**$ 10,577,899**
1996	**$ 5,051,501**
1997	**$ 7,680,816**
1998	**$ 18,473,968**
1999	**$ 14,670,381**
2000	**$ 10,963,341**
2001	**$ 21,619,720**
2002	**$ 22,893,024**
2003	**$ 24,406,095**
2004	**$ 14,512,608**
2005	**$ 23,861,437**
total	**$174,710,791**

Table 5.9	High Wear Rate	Base Wear Rate	Low Wear Rate
Long design life			
1995	$ 14,062,522	$ 7,410,341	$ 1,676,801
1996	$ 5,514,029	$ 4,230,787	$ 3,484,497
1997	$ 8,522,448	$ 5,172,927	$ 808,368
1998	$ 20,515,962	$ 5,677,584	$ 4,265,926
1999	$ 15,493,005	$ 5,998,608	$ 4,060,973
2000	$ 11,156,061	$ 18,633,704	$ 2,722,882
2001	$ 23,244,376	$ 13,244,191	$ 3,967,920
2002	$ 23,584,176	$ 12,154,742	$ 8,367,555
2003	$ 25,480,752	$ 13,650,384	$ 9,763,637
2004	$ 17,832,672	$ 16,173,168	$ 11,254,521
2005	$ 23,375,616	$ 17,817,360	$ 4,077,216
	$ 188,781,619	$ 120,163,795	$ 54,450,296
Base design life	**High Wear Rate**	**Base Wear Rate**	**Low Wear Rate**
1995	$ 10,577,899	$ 5,398,839	$ 1,676,801
1996	$ 5,051,501	$ 4,230,787	$ 1,710,594
1997	$ 7,680,816	$ 4,553,055	$ 805,728
1998	$ 18,473,968	$ 4,173,312	$ 3,472,051
1999	$ 14,670,381	$ 5,998,608	$ 3,942,701
2000	$ 10,963,341	$ 16,061,106	$ 2,560,258
2001	$ 21,619,720	$ 11,454,595	$ 3,890,832
2002	$ 22,893,024	$ 11,100,326	$ 7,672,707
2003	$ 24,406,095	$ 13,089,120	$ 1,326,336
2004	$ 14,512,608	$ 15,732,111	$ 7,253,846
2005	$ 23,861,437	$ 11,281,776	$ 3,483,294
	$ 174,710,791	$ 103,073,634	$ 37,795,148
Intermediate design life	**High Wear Rate**	**Base Wear Rate**	**Low Wear Rate**
1995	$ 5,473,118	$ 3,606,746	$ 1,676,801
1996	$ 4,970,717	$ 1,551,170	$ 1,005,945
1997	$ 5,474,304	$ 4,553,055	$ 805,728
1998	$ 9,958,537	$ 3,578,784	$ 1,403,858
1999	$ 8,805,866	$ 5,367,120	$ 3,562,541
2000	$ 11,348,253	$ 7,171,589	$ 2,160,576
2001	$ 17,835,544	$ 6,884,592	$ 3,506,448
2002	$ 17,174,784	$ 10,026,374	$ 5,608,709
2003	$ 20,193,480	$ 9,852,480	$ 622,512
2004	$ 19,048,837	$ 14,660,568	$ 4,805,510
2005	$ 23,163,993	$ 17,567,269	$ 3,659,118
	$ 143,447,433	$ 84,819,746	$ 28,817,745

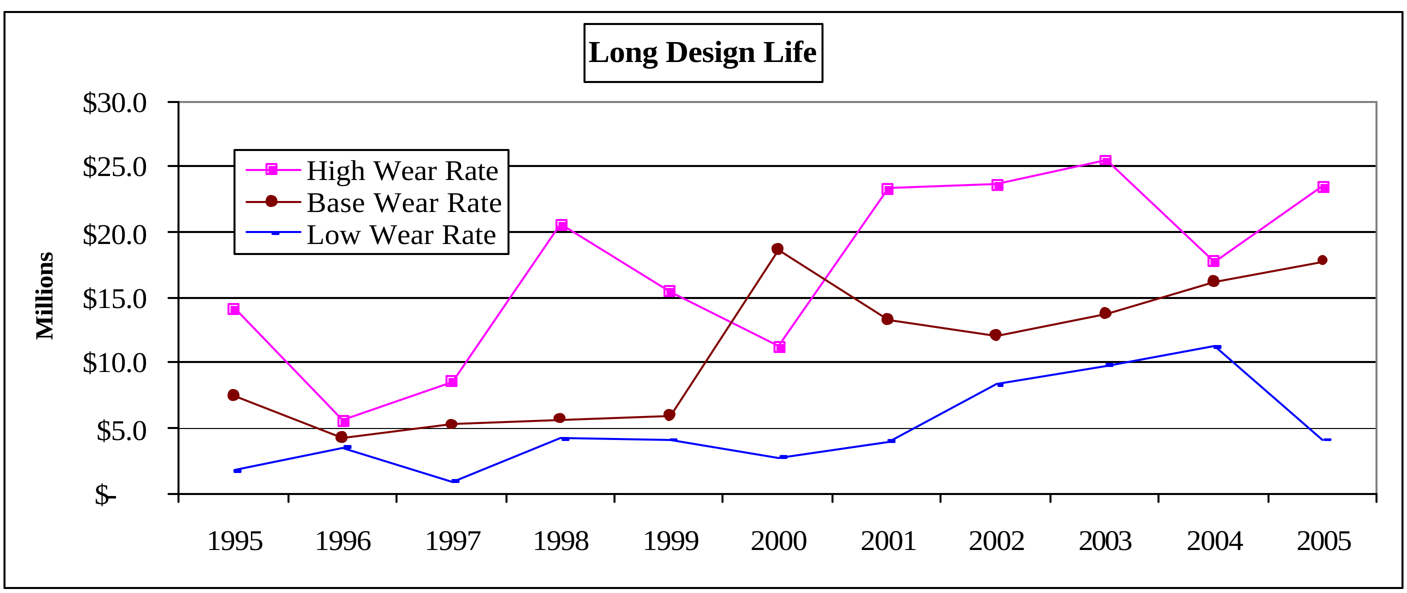
Figure 5.5



Base Design Life
$30.0
$25.0
$20.0
$15.0
$10.0
$5.0
$-
Millions
High Wear Rate
Base Wear Rate
Low Wear Rate
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005



Short Design Life
$25.0
$20.0
$15.0
$10.0
$5.0
$-
Millions
High Wear Rate
Base Wear Rate
Low Wear Rate
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005



Long Design Life
$30.0
$25.0
$20.0
$15.0
$10.0
$5.0
$-
Millions
High Wear Rate
Base Wear Rate
Low Wear Rate
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

5.3.3 Expenditure Projections Adjusted for Lightweight Studs

Beginning with the winter of 1996-97, studded tire sales in Oregon were restricted to tires with lightweight studs. Lightweight studs manufactured of lighter thin steel and some of non-steel materials are expected to reduce rutting by 30 to 50 percent (Barter, 1995; Gustafson, 1992). The expenditure projections were also adjusted for a second possibility. This possibility stems from the fact that studded tires generally last three or four seasons. Thus, the change to lightweight studs is expected to be gradual. In addition, a complete change to lightweight studs is unlikely because conventional studs are still available in neighboring states.

The projections for the each wear rate and design life are adjusted for four scenarios. The most optimistic scenario assumes a 50 percent wear rate reduction and an optimistic rapid change to lightweight studs. The most pessimistic scenario assumes only 30 percent wear reduction and a slower change to lightweight studs. Four possible change factors resulting from a switch to lightweight stud factors are shown in Table 5.10, and the associated expenditures for the Base Case are shown in Table 5.11. All other scenario adjustments are provided in Appendix H.

Table 5.10

Factor adjustment for lightweight stud wear reduction

	Optimistic lightweight studs	Pessimistic reduced wear	Factor	Optimistic lightweight studs	Optimistic reduced wear	Factor
1995	0%	50%	1	0%	35%	1
1996	0%	50%	1	0%	35%	1
1997	20%	50%	0.9	20%	35%	0.87
1998	40%	50%	0.8	40%	35%	0.74
1999	60%	50%	0.7	60%	35%	0.61
2000	80%	50%	0.6	80%	35%	0.48
2001	80%	50%	0.6	80%	35%	0.48
2002	80%	50%	0.6	80%	35%	0.48
2003	80%	50%	0.6	80%	35%	0.48
2004	80%	50%	0.6	80%	35%	0.48
2005	80%	50%	0.6	80%	35%	0.48

	Pessimistic lightweight studs	Pessimistic reduced wear	Factor	Pessimistic lightweight studs	Optimistic reduced wear	Factor
1995	0%	50%	1	0%	35%	1
1996	0%	50%	1	0%	35%	1
1997	10%	50%	0.95	10%	35%	0.935
1998	20%	50%	0.9	20%	35%	0.87
1999	30%	50%	0.85	30%	35%	0.805
2000	40%	50%	0.8	40%	35%	0.74
2001	50%	50%	0.75	50%	35%	0.675
2002	50%	50%	0.75	50%	35%	0.675
2003	50%	50%	0.75	50%	35%	0.675
2004	50%	50%	0.75	50%	35%	0.675
2005	50%	50%	0.75	50%	35%	0.675

Table 5.11 The effect of the lightweight studs on the Base case.

Long		Optimistic	Pessimistic	Optimistic	Optimistic	Pessimistic	Pessimistic	Pessimistic	Optimistic
Life		factor	expenditure	factor	expenditure	factor	expenditure	factor	expenditure
1995	7,410,341	1	$ 7,410,341	1	$ 7,410,341	1	$ 7,410,341	1	$ 7,410,341
1996	4,230,787	1	$ 4,230,787	1	$ 4,230,787	1	$ 4,230,787	1	$ 4,230,787
1997	5,172,927	0.9	$ 4,655,634	0.87	$ 4,500,446	0.95	$ 4,914,281	0.935	$ 4,836,687
1998	5,677,584	0.8	$ 4,542,067	0.74	$ 4,201,412	0.9	$ 5,109,826	0.87	$ 4,939,498
1999	5,998,608	0.7	$ 4,199,026	0.61	$ 3,659,151	0.85	$ 5,098,817	0.805	$ 4,828,879
2000	18,633,704	0.6	$ 11,180,222	0.48	$ 8,944,178	0.8	$ 14,906,963	0.74	$ 13,788,941
2001	13,244,191	0.6	$ 7,946,515	0.48	$ 6,357,212	0.75	$ 9,933,143	0.675	$ 8,939,829
2002	12,154,742	0.6	$ 7,292,845	0.48	$ 5,834,276	0.75	$ 9,116,056	0.675	$ 8,204,451
2003	13,650,384	0.6	$ 8,190,230	0.48	$ 6,552,184	0.75	$ 10,237,788	0.675	$ 9,214,009
2004	16,173,168	0.6	$ 9,703,901	0.48	$ 7,763,121	0.75	$ 12,129,876	0.675	$ 10,916,888
2005	17,817,360	0.6	$ 10,690,416	0.48	$ 8,552,333	0.75	$ 13,363,020	0.675	$ 12,026,718
	120,163,795		$ 80,041,984		$ 68,005,441		$ 96,450,898		$ 89,337,028

Base life		**Optimistic**	**Pessimistic**	**Optimistic**	**Optimistic**	**Pessimistic**	**Pessimistic**	**Pessimistic**	**Optimistic**
		factor	expenditure	factor	expenditure	factor	expenditure	factor	expenditure
1995	5,398,839	1	$ 5,398,839	1	$ 5,398,839	1	$ 5,398,839	1	$ 5,398,839
1996	4,230,787	1	$ 4,230,787	1	$ 4,230,787	1	$ 4,230,787	1	$ 4,230,787
1997	4,553,055	0.9	$ 4,097,749	0.87	$ 3,961,158	0.95	$ 4,325,402	0.935	$ 4,257,106
1998	4,173,312	0.8	$ 3,338,650	0.74	$ 3,088,251	0.9	$ 3,755,981	0.87	$ 3,630,781
1999	5,998,608	0.7	$ 4,199,026	0.61	$ 3,659,151	0.85	$ 5,098,817	0.805	$ 4,828,879
2000	16,061,106	0.6	$ 9,636,664	0.48	$ 7,709,331	0.8	$ 12,848,885	0.74	$ 11,885,219
2001	11,454,595	0.6	$ 6,872,757	0.48	$ 5,498,206	0.75	$ 8,590,946	0.675	$ 7,731,852
2002	11,100,326	0.6	$ 6,660,195	0.48	$ 5,328,156	0.75	$ 8,325,244	0.675	$ 7,492,720
2003	13,089,120	0.6	$ 7,853,472	0.48	$ 6,282,778	0.75	$ 9,816,840	0.675	$ 8,835,156
2004	15,732,111	0.6	$ 9,439,266	0.48	$ 7,551,413	0.75	$ 11,799,083	0.675	$ 10,619,175
2005	11,281,776	0.6	$ 6,769,066	0.48	$ 5,415,252	0.75	$ 8,461,332	0.675	$ 7,615,199
	103,073,634		**$ 68,496,470**		**$ 58,123,321**		**$ 82,652,156**		**$ 76,525,712**

Interm.		Optimistic	Pessimistic	Optimistic	Optimistic	Pessimistic	Pessimistic	Pessimistic	Optimistic
life		factor	expenditure	factor	expenditure	factor	expenditure	factor	expenditure
1995	3,606,746	1	$ 3,606,746	1	$ 3,606,746	1	$ 3,606,746	1	$ 3,606,746
1996	1,551,170	1	$ 1,551,170	1	$ 1,551,170	1	$ 1,551,170	1	$ 1,551,170
1997	4,553,055	0.9	$ 4,097,749	0.87	$ 3,961,158	0.95	$ 4,325,402	0.935	$ 4,257,106
1998	3,578,784	0.8	$ 2,863,027	0.74	$ 2,648,300	0.9	$ 3,220,906	0.87	$ 3,113,542
1999	5,367,120	0.7	$ 3,756,984	0.61	$ 3,273,943	0.85	$ 4,562,052	0.805	$ 4,320,532
2000	7,171,589	0.6	$ 4,302,953	0.48	$ 3,442,362	0.8	$ 5,737,271	0.74	$ 5,306,975
2001	6,884,592	0.6	$ 4,130,755	0.48	$ 3,304,604	0.75	$ 5,163,444	0.675	$ 4,647,100
2002	10,026,374	0.6	$ 6,015,824	0.48	$ 4,812,659	0.75	$ 7,519,780	0.675	$ 6,767,802
2003	9,852,480	0.6	$ 5,911,488	0.48	$ 4,729,190	0.75	$ 7,389,360	0.675	$ 6,650,424
2004	14,660,568	0.6	$ 8,796,341	0.48	$ 7,037,073	0.75	$ 10,995,426	0.675	$ 9,895,884
2005	17,567,269	0.6	$ 10,540,361	0.48	$ 8,432,289	0.75	$ 13,175,452	0.675	$ 11,857,907
	84,819,746		$ 55,573,399		$ 46,799,495		$ 67,247,009		$ 61,975,187

Chapter 6.

Summary of Findings

- Studded tires improve the braking, traction and cornering performance of vehicles on icy surfaces. The improved handling can be offset by a slight increase in driving speed. Researchers in the US and in the Scandinavian countries tend to find conflicting results regarding the net safety effects of studded tires. Numerous US studies have determined that there is not a net safety benefit from the use of studded tires. Many state highway agencies have recommended a prohibition on studded tires. Finland, Sweden, and Norway recently conducted a $30 million research program on studded tires. Their results indicate that studded tire use provides an overall safety benefit, despite the related drawbacks.

- The use of studded tires continues to grow in popularity. A survey conducted in 1995 revealed that about 16 percent of registered vehicles in Oregon were equipped with studded tires during the 1994-95 winter. Nearly half of users had studded tires on both axles. This yields an estimated 1.24 million studded tires in use during the year.

- Wide ranges of wear rates were found for various sections of PCC and asphalt pavements. This reflects the many factors that contribute to pavement rutting susceptibility. PCC is more resistant to rutting than asphalt. Within the asphalt pavements, there was no obvious advantage of open-graded mixes over dense-graded mixes. The PCC wear rate is about

0.0093 inches per 100,000 studded tire passes, while the wear rate of asphalt pavement is about 0.0386 inches per 100,000 studded tire passes.

- An estimate of the total pavement damage caused by studded tire in 1995 indicates a mitigation cost of about $30 million for the state highway system, and nearly $20 million for county and city roads. This $50.2 million estimate is the base case between a low of $30.7 and a high of $69.8 million.

- An estimate of effective pavement damage - damage sufficient to reduce the useful pavement life - indicates that mitigating damage caused by 1995 studded tire traffic will cost over $10 million for the state highway system alone. This is the base case scenario among nine different estimates ranging from $3.7 million on the low side to a maximum of $18.3 million.

- Expenditures for repairing studded tire damage for 11 years were projected to total around $103 million by 2005. This estimate represents the base pavement design life and base wear rate. The other nine scenarios range from $28.8 million up to a high of $188.8 million. All estimates are for the state highway system alone.

- The increased use of lightweight studs may reduce annual expenditures by as much as one-half and as little as one-third. The rate by which the introduction of the lightweight studs in the state interacts with the damage reduction, produces about four different scenarios for each of the nine estimates of the annual expenditures. For the base case of design life and wear rate, the 11-year expenditure of $103 million may take any of the four new values. The most optimistic will be a reduction of 43 percent of total expenditures to $58 million. The most pessimistic scenario will be a reduction of only 29 percent to $82.7 million. The two other scenarios are $76.5 and $68.5 million for the 11-year period. All estimates are for the state highway system alone.

- Considering that the studded tire season was shortened by about two months, and the introduction of newer technology tire alternatives, the damage of the pavements are expected to be reduced even further. However, the new trend of installing studded tires on all four tires of most vehicles, will push studded tire damage to the higher side. In balancing those two offsetting factors, it seems that the most plausible scenario for the 11-year expenditures will be somewhere between the Optimistic-Optimistic scenario of $58.1 million and the Optimistic-Pessimistic scenario of $68.5 million. An average of these two scenarios by year (Table 6.1) could serve as the most accurate expectation for the coming few years.

Base life	**Most Likely outcome. expenditure**	
1995	$5,398,839	
1996	$4,230,787	
1997	$4,029,454	
1998	$3,213,450	
1999	$3,929,088	
2000	$8,672,997	
2001	$6,185,481	
2002	$5,994,176	
2003	$7,068,125	
2004	$8,495,340	
2005	$6,092,159	
	$63,309,896	
Average Annual	**$5,755,445**	**1995-2005**
Average Annual	**$7,084,713**	**2000-2005**

Table 6.1

Chapter 7.

Conclusions and Recommendations

The main conclusion of this study is that studded tire use, regardless of its other benefits, inflicts certain amounts of damage to Oregon road systems. There has been a desire for many years by the different road agencies to reduce that damage. Several steps were taken to reduce the effects of studded tire damages. One of the important measures taken in Oregon was the legislation to require the studs sold in Oregon to be of the lightweight varieties. This change will spare Oregon highways somewhere between 43% and 29% of the costs of repairing studded tires damage. In addition, the studded tire season has been shortened by about two months, which will reduce damage further. A third positive measure has been the inclusion of the new soft-rubber tires in the traction tires class, which puts these new tires in parity with studded tires.

There were many attempts in the past few legislative sessions to prohibit the use of studded tires in Oregon. This option had worked in many other states in the past, where a number of northern (snow) states and many Canadian provinces outlawed the use of studded tires. This option remains a viable alternative in curbing studded tire damage. However, it seems that Oregon drivers, particularly on the eastside of the Cascades, obtain a strong sense of safety and winter driving security from using studded tires.

Another alternative that had been explored is to tax studded tires at the point of sale. This alternative attempts to accomplish a reduction in use (due to the higher price), as well as generate enough revenue to cover the costs of mitigating the damage. In order to cover expenditures, the tax on studded tire sales will need to be in the neighborhood of $30 per tire. At that price level, and in the absence of other controls, it might stimulate the sales of tires to out of state suppliers who do not have to comply with the proposed taxes. This effect would leave mitigation costs unpaid for, while the damage persists unaffected. In addition, the previous contention does not address the logistics of collecting and administering that tax.

The third alternative is to establish a program of studded tire permits. This program could resemble the snow-park permits where users of studded tires would purchase an annual permit for using studded tires on Oregon highways. This permit could apply to out of state users as a regular permit or on a single or multiple trip permit basis. The annual studded tire permit will need to be about $7 to $8 per tire to cover the level of annual expenditures and the costs of administering the program. However, enforcement and logistical details need to be explored further, although they seem to be less problematic than for the other alternative.

The fourth alternative remains a “do nothing” approach. The two measures mentioned above, namely the lightweight studs and the shortening of the season have already contributed to reducing the damage in the preceding years. Further advances in engineering design of pavements might add more reductions to studded tire pavement damage. However, this leaves a significant amount of expenditures uncovered by users and will eventually shift the costs to other passenger vehicle users.

The new tire design and technologies that have been introduced in the past few years need to be looked at as an alternative to studded tires. These new tires are acquiring more recognition as acceptable traction tires, and they constitute a viable alternative to studded tires. However, these tires might still be a little expensive for the typical consumer. These new tires will also need to overcome a psychological and a habitual by the consumer. Once these obstacles are overcome and a large transition to the soft-rubber tire technology is achieved, a large decrease in damage and expenditures will follow.

It is also reasonable to extrapolate a combination of any of the alternatives mentioned above. For example, a studded tire tax or permit might equalize the choice and the indifference of the consumer to the new tire technology. This is a plausible additional alternative. Other combination of the alternatives mentioned above are undoubtedly also feasible.

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Appendices

Appendix A: Rut Depth Data.

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
1	234.0	0.2887					
1	234.2	0.3300		0.2365	0.2493		0.4097
1	234.4			0.2454	0.2493		0.3998
1	234.6			0.2772	0.2117		0.1949
1	234.8			0.4643	0.2366		0.2233
1	235.0	0.3467		0.5142	0.2742		0.3404
1	235.2	0.3309		0.5409	0.3176		0.3384
1	235.4	0.3088		0.7072	0.3590		0.3492
1	235.6	0.2499		0.6186	0.2414		0.4243
1	235.8	0.2695		1.2011	0.2535		0.8372
1	236.0	0.1990		0.5631	0.3575		0.3063
1	236.2	0.3155		0.4392	0.3042		0.2754
1	236.4	0.3063		0.4020	0.3226		0.3684
1	236.6	0.3099		0.5336	0.3608		0.4010
1	236.8	0.3673		0.9994	0.2791		0.7103
1	237.0	0.2784		0.4465	0.3653		0.3735
1	237.2	0.2832		0.5681	0.3605		0.3925
1	237.4	0.2695		0.6102	0.2613		0.3388
1	237.6	0.3583		0.5218	0.3332		0.2922
1	237.8	0.3293		1.2385	0.2893		0.6757
1	238.0	0.3086		0.6227	0.2989		0.3894
1	238.2	0.2855		0.6136	0.2916		0.3715
1	238.4	0.3403		0.3768	0.2930		0.3471
1	238.6	0.3642		0.5242	0.3099		0.3147
1	238.8	0.3405		1.0369	0.3476		0.6707
1	239.0	0.2636		0.5432	0.3010		0.3594
1	239.2	0.2995		0.5454	0.2837		0.3593
1	239.4	0.3238		0.5672	0.2755		0.3593
1	239.6	0.4226		0.7034	0.3306		0.3594
1	239.8	0.3691		0.6242	0.3268		0.3593
1	240.0	0.5075		0.6635	0.2619		0.2795
1	240.2	0.4059		0.4441	0.1660		0.2078
1	240.4	0.3632		0.4418	0.2423		0.3788
1	240.6	0.2851		0.3189	0.2678		0.3387
1	240.8	0.3900		0.4289	0.2957		0.3491
1	241.0	0.3784		0.3359	0.3895		0.4069
1	241.2	0.3717		0.3891	0.3807		0.3687
1	241.4	0.4368		0.4704	0.2968		0.2858
1	241.6	0.4926		0.4481	0.2157		0.2299
1	241.8	0.5341		0.4584	0.2703		0.2803
1	242.0	0.5461		0.6431	0.2687		0.3382
1	242.2	0.5248		0.3729	0.2766		0.3455
1	242.4	0.3864		0.5805	0.2980		0.3021
1	242.6	0.5663		0.4751	0.2955		0.3354
1	242.8	0.4436		0.3021	0.3911		0.3464

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
1	243.0	0.3573		0.3509	0.2643		0.3925
1	243.2	0.4262		0.2785	0.2811		0.3770
1	243.4	0.5170		0.2954	0.3082		0.2986
1	243.6	0.4592		0.3868	0.2746		0.3343
1	243.8	0.4231		0.5229	0.2730		0.3142
1	244.0	0.5091		0.2924	0.1970		0.3040
1	244.2	0.5336		0.5707	0.1921		0.2789
1	244.4	0.3814		0.2664	0.2332		0.2484
1	244.6	0.3051		0.2031	0.2705		0.2167
1	244.8	0.2196		0.2441	0.2612		0.2164
1	245.0	0.2032		0.2633	0.2072		
1	245.2	0.2226		0.2780	0.1873		
1	245.4	0.2378		0.2852	0.2401		
1	245.6	0.2076		0.2895	0.2058		
1	245.8	0.1996		0.2283	0.2195		
1	246.0	0.2047		0.1919	0.2459		0.2935
1	246.2	0.2437		0.2451	0.2537		0.2694
1	246.4	0.2733		0.2459	0.2609		0.2407
1	246.6	0.2573		0.2431	0.2514		0.2672
1	246.8	0.2130		0.2261	0.2082		0.2672
1	247.0	0.2047		0.1847	0.2691		0.2507
1	247.2	0.2437		0.2707	0.2779		0.2409
1	247.4	0.2733		0.3192	0.2280		0.2219
1	247.6	0.2573		0.3188	0.2277		
1	247.8	0.2130		0.3050	0.2184		
1	248.0	0.2364		0.2880	0.2222		
1	248.2	0.3933		0.3257	0.2224		
1	248.4	0.3917		0.3334	0.3282		
1	248.6	0.2614		0.2836	0.2827		
1	248.8	0.2277		0.2104	0.2436		
1	249.0	0.2096		0.1959	0.4920		
1	249.2	0.2587		0.3040	0.3211		
1	249.4	0.2780		0.2593	0.2784		
1	249.6	0.3019		0.5169	0.2374		
1	249.8	0.3017		0.4935	0.2683		
1	250.0			0.3179	0.4184		
1	250.2			0.2918	0.4793		
1	250.6	0.3818					
1	250.8	0.3594					
1	258.0				0.2611		0.2362
1	259.0	0.2866	0.2811	0.2430	0.2787	0.1743	0.1661
1	259.2	0.3149	0.2791	0.2157	0.3022	0.1926	0.2019
1	259.4	0.3068	0.2936	0.2021	0.2775	0.2206	0.2404
1	259.6	0.2809	0.2621	0.1798	0.2667	0.2423	0.2391
1	259.8	0.3358	0.2307	0.2007	0.2797	0.2015	0.2039
1	260.0	0.3714	0.2091	0.2221	0.3360	0.1554	0.2141
1	260.2	0.3258	0.1871	0.2281	0.3852	0.1810	0.2083
1	260.4	0.3447	0.1455	0.2304	0.3963	0.1677	0.1991
1	260.6	0.3415	0.1543	0.2540	0.2731	0.1340	0.2230
1	260.8	0.3962	0.1693	0.2007	0.3215	0.1592	0.1666

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
1	261.0	0.4222	0.2418	0.2221	0.4172	0.1750	0.1944
1	261.2	0.3086	0.2239	0.2281	0.4457	0.1535	0.1979
1	261.4	0.3281	0.1982	0.2304	0.4561	0.1782	0.1819
1	261.6	0.3193	0.1463	0.2540	0.4086	0.1860	0.1792
1	261.8	0.2776	0.1739	0.2562	0.3491	0.2336	0.2629
1	262.0	0.2729	0.2043	0.2431	0.2854	0.1957	0.1705
1	262.2	0.2097	0.2058	0.2741	0.2830	0.1343	0.1989
1	262.4	0.1955	0.1842	0.2527	0.3029	0.1901	0.2004
1	262.6	0.2734	0.1722	0.2501	0.3283	0.1733	0.2088
1	262.8	0.3828	0.2286	0.2440	0.2473	0.1707	0.1872
1	263.0	0.4412	0.2108	0.2105	0.4686	0.1957	0.2338
1	263.2	0.3201	0.2590	0.2046	0.3875	0.2229	0.1597
1	263.4	0.3345	0.2270	0.1888	0.2899	0.2504	0.1888
1	263.6	0.2645	0.1815	0.2380	0.2759	0.2450	0.1720
1	263.8	0.3061	0.2136	0.2710	0.3471	0.2046	0.1899
1	264.0	0.2749	0.1467	0.2544	0.4015	0.2107	0.2044
1	264.2	0.2297	0.1670	0.2492	0.4375	0.1818	0.2176
1	264.4	0.2951	0.2554	0.2415	0.4561	0.2386	0.2173
1	264.6	0.3681	0.2831	0.2613	0.4571	0.1938	0.1946
1	264.8	0.3219	0.2640	0.2809	0.3861	0.2127	0.2056
1	265.0	0.4116	0.2486	0.3219	0.4338	0.2664	0.2078
1	265.2	0.3249	0.2490	0.2795	0.3888	0.2533	0.1939
1	265.4	0.3714	0.2133	0.2493	0.4316	0.2465	0.1937
1	265.6	0.4067	0.2508	0.2551	0.3655	0.1827	0.2042
1	265.8	0.3963	0.2304	0.2273	0.3299	0.2904	0.2587
1	266.0	0.4073	0.2539	0.2496	0.4316	0.2270	0.1673
1	266.2	0.2997	0.2219	0.2681	0.4709	0.2262	0.1641
1	266.4	0.3554	0.2438	0.2459	0.4324	0.2498	0.1948
1	266.6	0.3449	0.2188	0.2612	0.4179	0.2352	0.1772
1	266.8	0.3688	0.2210	0.2370	0.4411	0.2564	0.1907
1	267.0	0.3934	0.2527	0.2342	0.3656	0.2582	0.2019
1	267.2	0.4018	0.2766	0.2168	0.4084	0.2345	0.2201
1	267.4	0.3973	0.2751	0.2213	0.4438	0.2294	0.1964
1	267.6	0.2350	0.2504	0.2338	0.4099	0.2052	0.1771
1	267.8	0.2687	0.2309	0.2343	0.4511	0.2292	0.1833
1	268.0	0.3423	0.2202	0.2277	0.4646	0.2532	0.2344
1	268.2	0.3566	0.2623	0.2575	0.4679	0.2691	0.2500
1	268.4	0.3620	0.2722	0.2543	0.4731	0.2404	0.2376
1	268.6	0.3296	0.2695	0.2554	0.4019	0.2236	0.2502
1	268.8	0.3208	0.2656	0.2639	0.4403	0.1939	0.2034
1	269.0	0.3188	0.2032	0.2629	0.4384	0.3113	0.2558
1	269.2	0.2907	0.2558	0.2259	0.3865	0.2613	0.2340
1	269.4	0.3282	0.2109	0.2580	0.3299	0.2345	0.2778
1	269.6	0.4067	0.2821	0.2498	0.3879	0.2356	0.1840
1	269.8	0.3303	0.2404	0.2488	0.3494	0.2513	0.2281
1	270.0	0.3095	0.1841	0.2626	0.2855	0.1867	0.1753
1	270.2	0.3293	0.2432	0.2430	0.4164	0.2453	0.1763
1	270.4	0.3639	0.2437	0.2763	0.3468	0.2117	0.2061
1	270.6	0.3202	0.2596	0.2403	0.4587	0.2770	0.2182
1	270.8	0.3470	0.2907	0.2391	0.4261	0.3134	0.2346

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
1	271.0	0.4007	0.2626	0.2558	0.2549	0.2481	0.1447
1	271.2	0.4278	0.2795	0.2699	0.3572	0.2364	0.1684
1	271.4	0.3254	0.2610	0.2175	0.3348	0.2269	0.1717
1	271.6	0.4172	0.2626	0.2007	0.3929	0.2616	0.1977
1	271.8	0.3742	0.2506	0.2331	0.4251	0.2654	0.2078
1	272.0	0.7304	0.2604	0.3810	0.7196	0.5941	0.2879
1	272.2	0.6500	0.2752	0.5354	0.8297	0.4690	0.3191
1	272.4	0.3157	0.2279	0.2505	0.4146	0.3024	0.1932
1	272.6		0.2528				
1	272.8		0.2395				
1	273.0	0.3439	0.2221	0.2614	0.3650	0.2542	0.1029
1	273.2	0.3621	0.2043	0.2522	0.3192	0.3063	0.1466
1	273.4	0.2202	0.2085	0.2647	0.2931	0.3142	0.1576
1	273.6	0.3596	0.2146	0.2334	0.2962	0.3169	0.1771
1	273.8	0.3301	0.2152	0.2101	0.2898	0.2954	0.1528
1	274.0	0.3574	0.2389	0.2044	0.2878	0.2683	0.1480
1	274.2	0.3311	0.2870	0.2580	0.2895	0.3079	0.1299
1	274.4	0.3756	0.2833	0.2282	0.3393	0.2806	0.1477
1	274.6	0.3561	0.2894	0.2560	0.3239	0.2470	0.1453
1	274.8	0.3059	0.2545	0.2419	0.1840	0.2368	0.1233
1	275.0	0.3738	0.2754	0.2499	0.4157	0.3467	0.1955
1	275.2	0.3027	0.2455	0.2200	0.4561	0.3492	0.2084
1	275.4	0.2882	0.2303	0.1792	0.4020	0.2982	0.2171
1	275.6	0.3297	0.2273	0.1862	0.4076	0.3343	0.2317
1	275.8	0.2845	0.2180	0.2085	0.3048	0.2853	0.1863
1	276.0	0.3198	0.2746	0.2367	0.3992	0.2342	0.1691
1	276.2	0.3340	0.2798	0.1922	0.3942	0.2509	0.2131
1	276.4	0.3595	0.3342	0.2213	0.3877	0.3092	0.1790
1	276.6	0.3489	0.3179	0.2442	0.3878	0.2873	0.1844
1	276.8	0.3196	0.2729	0.2568	0.3336	0.3491	0.1778
1	277.0	0.2911	0.2719	0.2356	0.3895	0.1796	0.1361
1	277.2	0.3254	0.2374	0.2311	0.3335	0.1981	0.1745
1	277.4	0.3339	0.2435	0.2521	0.2689	0.2390	0.2240
1	277.6	0.2682	0.2495	0.2753	0.3598	0.2417	0.2009
1	277.8	0.2772	0.2768	0.3108	0.4217	0.2581	0.1645
1	278.0	0.2467	0.3001	0.3050	0.3591	0.3127	0.2461
1	278.2	0.3409	0.2492	0.3085	0.3907	0.2655	0.2157
1	278.4	0.3533	0.2294	0.2320	0.4169	0.3130	0.1843
1	278.6	0.3861	0.2737	0.2467	0.3982	0.2100	0.2126
1	278.8	0.3142	0.3158	0.2747	0.4021	0.2948	0.2311
1	279.0	0.3225	0.2918	0.2591	0.4117	0.3087	0.1926
1	279.2	0.3183	0.2602	0.2654	0.3803	0.3357	0.2026
1	279.4	0.3180	0.2530	0.2452	0.3712	0.2985	0.2825
1	279.6	0.3260	0.2382	0.2592	0.3826	0.3504	0.2334
1	279.8	0.3831	0.2788	0.1805	0.3078	0.3325	0.2675
1	280.0	0.3506	0.3995	0.2206	0.2597	0.1865	0.1927
1	280.2	0.3339	missing	0.2331	0.3678	0.3030	0.2119
1	280.4	0.3552	missing	0.2127	0.3659	0.3157	0.1413
1	280.6	0.3985	missing	0.2010	0.3950	0.2838	0.2119
1	280.8	0.3270	missing	0.2123	0.4313	0.2739	0.2098

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
1	281.0	0.3599	missing	0.2071	0.1794	0.3017	0.1505
1	281.2	0.2753	missing	0.2114	0.1534	0.3006	0.1471
1	281.4	0.2412	missing	0.1166	0.1580	0.2825	0.1398
1	281.6	0.2298	missing	0.1173	0.2441	0.2667	0.1843
1	281.8	0.2144	missing	0.1716	0.3146	0.2376	0.2239
1	282.0	0.1991	missing	0.1369	0.1705	0.2722	0.1690
1	282.2	0.2725	missing	0.1743	0.1543	0.2897	0.1283
1	282.4	0.2345	missing	0.2089	0.1828	0.2642	0.1948
1	282.6	0.1759	missing	0.1742	0.2326	0.2302	0.1911
1	282.8	0.1559	missing	0.1283	0.1742	0.2770	0.2020
1	283.0	0.3191	missing	0.1722	0.4292	0.3694	0.3477
1	283.2	0.3375	missing	0.3591	0.4624	0.3273	0.3115
1	283.4	0.2860	missing	0.2960	0.4820	0.3792	0.4680
1	283.6	0.3177	missing	0.2212	0.5076	0.2792	0.2713
1	283.8	0.2839	missing	0.2874	0.3313	0.2943	0.1937
1	284.0	0.3440	missing	0.2348	0.4492	0.3942	0.3368
1	284.2	0.5250	missing	0.2563	0.5684	0.3545	0.3267
1	284.4	0.5361	missing	0.2688	0.4076	0.3796	0.3270
1	284.6	0.5697	missing	0.2155	0.4797	0.2784	0.2304
1	284.8	0.4956	missing	0.2799	0.5159	0.3189	0.2169
1	285.0	0.3370	missing	0.2899	0.4836	0.3030	0.2415
1	285.2	0.1846	missing	0.2949	0.4150	0.3563	0.2691
1	285.4	0.2707	missing	0.2712	0.4279	0.3755	0.2868
1	285.6	0.3635	missing	0.2709	0.5073	0.3856	0.2604
1	285.8	0.2197	missing	0.1845	0.3113	0.3840	0.3082
1	286.0	0.9037	missing	0.5104	0.4105	0.6786	0.5265
1	286.2	1.0449	missing	0.5517	0.5983	0.4496	0.2258
1	286.4	0.4749	missing	0.2028	0.6545	0.5080	0.2662
1	286.6		missing	0.3079	0.6394	0.4686	0.2523
1	286.8		missing	0.2819	0.5467	0.4066	0.2742
1	287.0	0.4603	missing	0.3389	0.5602	0.3245	0.2988
1	287.2	0.4702	missing	0.2835	0.5149	0.3966	0.2993
1	287.4	0.4073	missing	0.3005	0.4203	0.3833	0.2815
1	287.6	0.2646	missing	0.2851	0.5208	0.4336	0.3309
1	287.8	0.4281	missing	0.2455	0.4747	0.4310	0.2568
1	288.0	0.4584	missing	0.2617	0.3944	0.3489	0.2876
1	288.2	0.4798	missing	0.3059	0.4163	0.2912	0.2877
1	288.4	0.4509	missing	0.2543	0.4998	0.3563	0.2866
1	288.6	0.4096	missing	0.2202	0.5207	0.3517	0.2745
1	288.8	0.3635	missing	0.3198	0.4445	0.3571	0.4338
1	289.0	0.2791	missing	0.3275	0.4614	0.2682	0.2928
1	289.2	0.3004	missing	0.3383	0.4091	0.2501	0.3223
1	289.4	0.3477	missing	0.2545	0.3453	0.1777	0.3033
1	289.6	0.3333	missing	0.3956	0.3435	0.3015	0.3296
1	289.8	0.4227	missing	0.3640	0.3190	0.3112	0.4425
1	290.0	0.2960	missing	0.3080	0.5513	0.3241	0.4222
1	290.2	0.2678	missing	0.2774	0.5038	0.2386	0.3444
1	290.4	0.3019	missing	0.3073	0.4789	0.2012	0.2647
1	290.6	0.2918	missing	0.4330	0.4110	0.2311	0.3334
1	290.8	0.4733	missing	0.3444	0.4660	0.3155	0.3180

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
1	291.0	0.4841	missing	0.4117	0.4029	0.2802	0.4611
1	291.2	0.3291	missing	0.3557	0.4366	0.3102	0.4133
1	291.4	0.3799	missing	0.2744	0.4648	0.2965	0.4516
1	291.6	0.3806	missing	0.3050	0.4759	0.3099	0.3806
1	291.8	0.3728	missing	0.2017	0.5035	0.3229	0.3147
1	292.0	0.3834	missing	0.1767	0.3250	0.3428	0.2624
1	292.2	0.3313	missing	0.1717	0.3670	0.2762	0.3077
1	292.4	0.3226	missing	0.2106	0.4715	0.3128	0.2476
1	292.6	0.3075	missing	0.1875	0.3845	0.2477	0.2660
1	292.8	0.2763	missing	0.1500	0.4121	0.2623	0.1966
1	293.0	0.2669	missing	0.2296	0.2311	0.2914	0.2829
1	293.2	0.3773	missing	0.2629	0.3388	0.3110	0.3230
1	293.4	0.3886	missing	0.1798	0.2794	0.3830	0.2363
1	293.6	0.3243	missing	0.2506	0.3216	0.2707	0.2443
1	293.8	0.3592	missing	0.1937	0.2533	0.2810	0.4579
1	294.0	0.2635	missing	0.3048	0.2521	0.2607	0.4264
1	294.2	0.3606	missing	0.3402	0.1924	0.2993	0.4755
1	294.4	0.4035	missing	0.4912	0.4398	0.4291	0.4914
1	294.6	0.4495	missing	0.5201	0.5702	0.4559	0.2860
1	294.8	0.5428	missing	0.3606	0.5155	0.3526	0.4168
1	295.0	0.4551	missing	0.2429	0.5046	0.4064	0.4372
1	295.2	0.3961	missing	0.3847	0.4743	0.2884	0.4204
1	295.4	0.5177	missing	0.4270	0.4464	0.3410	0.4204
1	295.6	0.4569	missing	0.4976	0.4981	0.4967	0.3949
1	295.8	0.3912	missing	0.3370	0.4778	0.3689	0.3296
1	296.0	0.4518	missing	0.3975	0.5127	0.5241	0.3018
1	296.2	0.5267	missing	0.3820	0.5595	0.4027	0.2737
1	296.4	0.4916	missing	0.4520	0.5066	0.4305	0.4092
1	296.6	0.4722	missing	0.4991	0.4832	0.3666	0.3373
1	296.8	0.5339	missing	0.5586	0.4925	0.3953	0.3723
1	297.0	0.5806	missing	0.3985	0.6324	0.4883	0.4413
1	297.2	0.4300	missing	0.4319	0.6729	0.7692	0.4510
1	297.4	0.4673	missing	0.4751	0.8806	0.7122	0.3016
1	297.6	0.5515	missing	0.4514	0.5710	0.3923	0.3536
1	297.8	0.4993	missing	0.4162	0.4284	0.3401	0.3450
1	298.0	0.4896	missing	0.3539	0.6550	0.3980	0.3751
1	298.2	0.2935	missing	0.4181	0.4716	0.3906	0.4105
1	298.4	0.5831	missing	0.5652	0.5428	0.5219	0.4043
1	298.6	0.7325	missing	0.3486	0.5433	0.3213	0.3951
1	298.8	0.4986	missing	0.2969	0.4206	0.4240	0.3432
1	299.0	0.3951	missing	0.2942	0.3404	0.3720	0.2856
1	299.2	0.5118	missing	0.2486	0.3236	0.5141	0.3070
1	299.4	0.5675	missing	0.2411	0.5087	0.4649	0.3627
1	299.6	0.2279	missing	0.3946			0.4680
1	299.8	0.4087	missing				
2	17.0	0.2868		0.3290	0.2053		0.2734
2	17.2	0.2543		0.6446	0.1717		0.2185
2	18.0	0.2858		0.5652	0.2062		0.3752
2	18.2	0.2390		0.7337	0.2833		0.3176
2	18.4	0.3099		0.6837	0.2705		0.4396

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
2	18.6	0.3171		0.5639	0.2619		0.5046
2	18.8	0.3611		0.3924	0.3064		0.4491
2	19.0	0.3677		0.4346	0.2602		0.4884
2	19.2	0.2855		0.4237	0.2188		0.4191
2	19.4	0.2908		0.3982	0.2579		0.4528
2	19.6	0.4190		0.6126	0.2399		0.4581
2	19.8	0.3029		0.7082	0.2765		0.3919
2	20.0	0.4084		0.4662	0.3405		0.3941
2	20.2	0.3069		0.4029	0.4606		0.5413
2	20.4	0.4543		0.4862	0.3958		0.4813
2	20.6	0.5251		0.5656	0.3724		0.5582
2	20.8	0.5022		0.5717	0.2526		0.4769
2	21.0	0.4084		0.6200	0.3397		0.3643
2	21.2	0.3069		0.5512	0.4340		0.4241
2	21.4	0.4543		0.5474	0.3559		0.4841
2	21.6	0.5251		0.5128	0.3956		0.3800
2	21.8	0.5022		0.3653	0.3392		0.4393
2	22.0	0.4213		0.4574	0.2844		0.2985
2	22.2	0.4444		0.4319	0.2904		0.3216
2	22.4	0.2950		0.3544	0.2581		0.3131
2	22.6	0.3522		0.3269	0.3813		0.5068
2	22.8	0.3407		0.3433	0.2539		0.4031
2	23.0	0.3838		0.4574	0.2892		0.3484
2	23.2	0.3853		0.4319	0.2678		0.3669
2	23.4	0.3976		0.3544	0.2862		0.3592
2	23.6	0.3831		0.3269	0.3082		0.3726
2	23.8	0.3765		0.3433	0.2530		0.2583
2	24.0	0.2741		0.2816	0.2318		0.2755
2	24.2	0.3003		0.3195	0.2176		0.2282
2	24.4	0.2787		0.3485	0.2196		0.3077
2	24.6	0.2699		0.3753	0.2307		0.2871
2	24.8	0.2825		0.3180	0.2232		0.3459
2	25.0	0.2643		0.3354	0.2958		0.3543
2	25.2	0.2665		0.3182	0.3101		0.3887
2	25.4	0.2865		0.3023	0.3195		0.3778
2	25.6	0.3168		0.3373	0.3089		0.3643
2	25.8	0.3097		0.3494	0.2480		0.2536
2	26.0	0.2960		0.2565	0.2392		0.3628
2	26.2	0.3109		0.2714	0.2734		0.3150
2	26.4	0.3548		0.3001	0.2248		0.2754
2	26.6	0.3138		0.4535	0.2199		0.2722
2	26.8	0.3207		0.4209	0.2943		0.2974
2	27.0	0.2925		0.4789	0.2380		0.3019
2	27.2	0.3348		0.4781	0.2519		0.2892
2	27.4	0.3134		0.4446	0.2421		0.3273
2	27.6	0.2711		0.3810	0.2148		0.2247
2	27.8	0.3128		0.3843	0.2270		0.3450
2	28.0	0.3014		0.3639	0.2854		0.3085
2	28.2	0.2789		0.3518	0.2447		0.2362
2	28.4	0.2430		0.4105	0.2339		0.2426

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
2	28.6	0.2467		0.3168	0.2150		0.2615
2	28.8	0.2435		0.3902	0.2322		0.3332
2	29.0	0.3235		0.4024	0.3021		0.3307
2	29.2	0.2990		0.4485	0.2832		0.3469
2	29.4	0.3031		0.4398	0.2908		0.3776
2	29.6	0.2970		0.4461	0.2856		0.3390
2	29.8	0.2910		0.4224	0.2962		0.3293
2	30.0	0.2553		0.3840	0.3277		0.2799
2	30.2	0.2814		0.3625	0.3489		0.2699
2	30.4	0.2708		0.3455	0.3056		0.2884
2	30.6	0.2559		0.3362	0.2880		0.3825
2	30.8	0.2643		0.2716	0.3072		0.3412
2	31.0	0.3010		0.3288	0.2118		0.2137
61	0.0	0.3226		0.2606	0.2604		0.2915
61	0.2	0.3565		0.3261	0.5502		0.4343
61	0.4	0.3895		0.3664	0.5401		0.4844
61	0.6	0.2832		0.3457	0.3757		0.3103
61	0.8	0.2724		0.3507	0.2694		0.3064
61	1.0	0.3085		0.4745	0.2879		0.3667
61	1.2	0.3439		0.5273	0.2711		0.3908
61	1.4	0.2750		0.5496	0.2192		0.3188
61	1.6	0.2671		0.3565	0.4544		0.4200
61	1.8	0.2172		0.4856	0.2910		0.4551
61	2.0	0.3787		0.6103	0.2193		0.4222
61	2.2	0.3077		0.4046	0.2517		0.4720
61	2.4	0.3250		0.2438	0.2190		0.6129
61	2.6	0.3402		0.3283	0.3517		0.5186
61	2.8	0.4843		0.3684	0.3925		0.4743
61	3.0	0.3829		0.1241	0.4349		0.4322
61	3.2	0.4233		0.2487	0.3860		0.3415
61	3.4	0.3080		0.3221	0.2341		0.2925
61	3.6	0.3492		0.3604	0.2761		0.4234
61	3.8	0.3310		0.3109	0.2038		0.4513
61	4.0	0.3328		0.3153	0.2225		0.2328
64	0.0	0.2628		0.2712	0.2515		0.1846
64	0.2	0.1961		0.2217	0.2877		0.2570
64	0.4	0.1941		0.2083	0.4193		0.4485
64	0.6	0.1603		0.2217	0.4250		0.3277
64	0.8	0.2672		0.2450	0.2432		
64	1.0	0.2040		0.1821	0.3792		0.4485
64	1.2	0.4553		0.3347	0.3779		0.4155
64	1.4	0.3679		0.4108	0.3149		0.4191
64	1.6	0.3409		0.4195	0.3219		0.4044
64	1.8	0.4211		0.2755	0.3219		
64	2.0	0.4759		0.3642	0.4346		0.3485
64	2.2	0.4639		0.3677	0.3482		0.3422
64	2.4	0.4282		0.3755	0.4268		0.3608
64	2.6	0.3992		0.3614	0.3041		0.3543
64	2.8	0.4142		0.2821	0.3715		0.4358
64	3.0	0.3923		0.2261	0.4473		0.4071

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
64	3.2	0.3264		0.3555	0.4381		0.4684
64	3.4	0.3814		0.3428	0.3548		0.4085
64	3.6	0.4810		0.4911	0.3956		0.4096
64	3.8	0.3548		0.3849	0.3010		0.4041
64	4.0	0.4707		0.3924	0.3151		0.4283
64	4.2	0.4572		0.4380	0.4703		0.4701
64	4.4	0.4481		0.3775	0.5250		0.5150
64	4.6	0.4521		0.4240	0.4686		0.5150
64	4.8	0.4574		0.4373	0.5060		0.4299
64	5.0	0.4646		0.4049	0.4097		0.4397
64	5.2	0.4709		0.3840	0.4021		0.3871
64	5.4	0.4708		0.4270	0.3662		0.3953
64	5.6	0.4315		0.3268	0.3266		0.4044
64	5.8	0.4110		0.3733	0.5122		0.4524
64	6.0	0.4775		0.3770	0.4766		0.3386
64	6.2	0.3906		0.3093	0.4701		0.2915
64	6.4	0.4193		0.2757	0.4715		0.4211
64	6.6	0.5024		0.3570	0.4327		0.4340
64	6.8	0.4235		0.3077	0.3760		0.3591
64	7.0	0.4630		0.4059	0.3752		0.3700
64	7.2	0.5076		0.3463	0.3842		0.4277
64	7.4	0.4657		0.3586	0.4724		0.4450
64	7.6	0.4208		0.3794	0.2693		0.3900
64	7.8	0.4575		0.4123	0.3852		0.4467
64	8.0	0.4213		0.4378	0.3942		0.2656
64	8.2	0.3385		0.3499	0.3098		0.3720
64	8.4	0.4616		0.3682	0.4123		0.3713
64	8.6	0.4027		0.4115	0.4360		0.3980
64	8.8	0.3338		0.3199	0.3811		0.3296
64	9.0	0.3906	0.3415	0.2345	0.7825	0.3567	0.2537
64	9.2	0.2613	0.4102	0.3667	0.3989	0.3950	0.3456
64	9.4	0.3145	0.3732	0.2855	0.4437	0.4318	0.2932
64	9.6	0.5306		0.2770	0.2571		0.3187
64	9.8	0.4574		0.3247	0.2587		0.3411
64	10.0	0.3428	0.2829	0.2503	0.4791	0.3216	0.3953
64	10.2	0.4372	0.2890	0.2207	0.4583	0.3754	0.3234
64	10.4	0.4860	0.2889	0.2163	0.3315	0.2997	0.3166
64	10.6	0.5363	0.3665	0.4001	0.2558	0.2848	0.2034
64	10.8	0.4998	0.3461	0.3450	0.3181	0.3051	0.2340
64	11.0	0.5958	0.3906	0.3546	0.5675	0.2690	0.3797
64	11.2	0.5880	0.3463	0.3774	0.4140	0.3217	0.3714
64	11.4	0.5456	0.3226	0.2735	0.4906	0.3495	0.3421
64	11.6	0.5854	0.3413	0.3675	0.4128	0.2360	0.2779
64	11.8	0.5606	0.3104	0.3707	0.4849	0.3790	0.3919
64	12.0	0.3899	0.3174	0.3459	0.5245	0.2698	0.3129
64	12.2	0.4983	0.3345	0.2653	0.6017	0.3200	0.3596
64	12.4	0.5702	0.3694	0.2358	0.6331	0.3216	0.2992
64	12.6	0.5285	0.3430	0.3294	0.5771	0.3298	0.3111
64	12.8	0.3743	0.2731	0.2737	0.5608	0.3006	0.2929
64	13.0	0.4084	0.3177	0.2550	0.5352	0.3063	0.1669

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
64	13.2	0.4626	0.3283	0.3627	0.5046	0.2667	0.1992
64	13.4	0.4103	0.2540	0.3474	0.3972	0.2646	0.1697
64	13.6	0.2651	0.2659	0.2418	0.3463	0.2767	0.2150
64	13.8	0.3592	0.2020	0.2019	0.4532	0.3190	0.2814
64	14.0	0.2416	0.2262	0.1980	0.5038	0.3229	0.2415
64	14.2	0.3383	0.2246	0.2379	0.4212	0.3637	0.2106
64	14.4	0.3539	0.2639	0.3254	0.4452	0.3440	0.2685
64	14.6	0.3035	0.1803	0.2999	0.4045	0.3405	0.2581
64	14.8	0.2092	0.1878	0.2489	0.4594	0.3126	0.2289
64	15.0	0.2745	0.1917	0.2415	0.5461	0.4475	0.3058
64	15.2	0.3665	0.2824	0.2494	0.4103	0.3298	0.3230
64	15.4	0.4016	0.3467	0.2962	0.4559	0.2830	0.3360
64	15.6	0.4148	0.3241	0.2195	0.4710	0.2936	0.2550
64	15.8	0.4996	0.2202	0.3068	0.5260	0.3258	0.2873
64	16.0	0.4014	0.4067	0.3345	0.3750	0.3225	0.2675
64	16.2	0.4425	0.3316	0.2981	0.4382	0.4176	0.3806
64	16.4	0.5670	0.3926	0.3231	0.6263	0.4105	0.4197
64	16.6	0.4817	0.3443	0.3506	0.6810	0.4606	0.3852
64	16.8	0.2524	0.3247	0.2994	0.6262	0.4256	0.3576
64	17.0	0.5449	0.3664	0.4359	0.3028	0.3089	0.2512
64	17.2	0.4609	0.3590	0.4307	0.2298	0.1895	0.2532
64	17.4	0.3280	0.3571	0.2659	0.2258	0.2874	0.2540
64	17.6	0.4057	0.3207	0.3342	0.3994	0.3931	0.3599
64	17.8	0.4768	0.3431	0.3137	0.5625	0.3753	0.3557
64	18.0	0.3897	0.3075	0.2417	0.2764	0.3764	0.3014
64	18.2	0.4678	0.3553	0.3363	0.2867	0.2810	0.3593
64	18.4	0.5200	0.2871	0.4073	0.3119	0.2472	0.2990
64	18.6	0.5095	0.2576	0.3896	0.4182	0.2084	0.2685
64	18.8	0.4108	0.2534	0.2753	0.2575	0.1869	0.2281
64	19.0	0.2583	0.2099	0.2180	0.2305	0.3314	0.1998
64	19.2	0.2885	0.2674	0.2331	0.3405	0.2543	0.2195
64	19.4	0.2770	0.3028	0.2575	0.3794	0.2329	0.2495
64	19.6	0.2243	0.3379	0.3052	0.2984	0.3016	0.1580
64	19.8	0.3356	0.3274	0.3529	0.4085	0.3428	0.2210
64	20.0	0.3676	0.3224	0.3688	0.2135	0.2812	0.2752
64	20.2	0.2734	0.3894	0.3721	0.2036	0.1933	0.2632
64	20.4	0.2363	0.3026	0.3792	0.1832	0.2590	0.2784
64	20.6	0.3085	0.3025	0.3004	0.2752	0.2816	0.2821
64	20.8	0.2665	0.3142	0.3674	0.3022	0.3445	0.3006
64	21.0	0.2817	0.3238	0.2280	0.2533	0.1825	0.1947
64	21.2	0.2983	0.3254	0.2456	0.2603	0.2494	0.1616
64	21.4	0.2913	0.2610	0.2341	0.2651	0.2126	0.1709
64	21.6	0.3165	0.2504	0.2767	0.2809	0.2580	0.1568
64	21.8	0.2325	0.3048	0.2686	0.2367	0.2625	0.1716
64	22.0	0.2661	0.3273	0.2520	0.3572	0.3473	0.3586
64	22.2	0.2396	0.2734	0.2156	0.3847	0.3487	0.3818
64	22.4	0.2484	0.2680	0.2078	0.2921	0.3031	0.2357
64	22.6	0.2548	0.2657	0.2138	0.2370	0.2285	0.2474
64	22.8	0.3445	0.3085	0.2912	0.2179	0.1834	0.1611
64	23.0	0.3354	0.3056	0.3451	0.2876	0.3134	0.2590

HWY NO	MP	N/E Left	N/E Center	N/E Right	S/W Left	S/W Center	S/W Right
64	23.2	0.4217	0.3572	0.3713	0.3207	0.2997	0.2341
64	23.4	0.4316	0.3430	0.3963	0.3350	0.2553	0.2321
64	23.6	0.3140	0.2513	0.2688	0.3813	0.2512	0.2514
64	23.8	0.2652	0.2232	0.3135	0.3941	0.3561	0.3339
64	24.0	0.2701	0.2409	0.2863	0.3034	0.2511	0.2188
64	24.2	0.3060	0.2741	0.2732	0.2669	0.2290	0.2612
64	24.4	0.2260	0.2309	0.2267	0.3068	0.2027	0.1581
64	24.6	0.2132	0.2506	0.2484	0.2206	0.2264	0.1859
64	24.8	0.3015	0.2762	0.2602	0.2685	0.3062	0.2064
64	25.0	0.2815	0.2673	0.2924	0.3055	0.2048	0.1933
64	25.2	0.3015	0.2591	0.2949	0.2831	0.2426	0.2364
64	25.4	0.3136	0.2912	0.2923	0.2955	0.2425	0.2167
64	25.6	0.2913	0.2846	0.3307	0.2989	0.2145	0.2338
64	25.8	0.2976	0.2494	0.3383	0.3015	0.2367	0.2376
64	26.0	0.2724	0.2559	0.2625	0.3085	0.2393	0.1970
64	26.2	0.2319	0.2228	0.2323	0.3329	0.2504	0.2105
64	26.4	0.2306	0.2520	0.2256	0.3177	0.2484	0.1824
64	26.6		0.2093				

Hwy Data Guide

filename c:\...\data\		mileposts	CHECK 1.065	ATTACH	SORT	
I-5	LANE	MP 234.17-250.31				
001AX12	SR					
001AX13						
001AX21	NR					
001AX22						
001AX23						
001AX31	SL					
001AX32						
001AX33						
001AX41	NL					
001AX42						
001AX43						
I-5		MP 258.96-299.93				
001BX11	NR					
001BX12						
001BX13						
001BX21	SR					
001BX22						
001BX23						
001BX31	NC					
001BX32						
001BX33						
001BX41	SC					
001BX42						
001BX43						

001BX51	NL					
001BX52						
001BX53						
001BX61	SL					
001BX62						
001BX63						
I-84	I-84	MP 17.75-31.17	CHECK 1.065			
002X11	EL					
002X12						
002X13						
002X21	WL					
002X22						
002X23						
002X31	ER					
002X32						
002X33						
002X41	WR					
002X42						
002X43						
	I-405	MP 0.04-4.21	CHECK 1.065			
061X1	SL					
061X2	NL					
061X3	SR					
061X4	NR					
	I-205	MP 9.03-26.6	CHECK 1.065			
064X11	SC					
064X12						
064X13						
064X21	NC					
064X22						
064X23						
064X31	SL	MP 1.0-26.6				
064X32						
064X33						
064X41	NL					
064X42						
064X43						
064X51	NR					
064X52						
064X53						
064X61	SR					
064X62						
064X63						

Appendix B: Factors for Passenger Vehicles and Monthly Volumes.

Interstate 5

Permanent Counter 03-011

Month	ADT	% of ADT	# of Days	Monthly Traffic	Annual Traffic (AADT * 365)	Monthly Traffic Factor
January	53,000	79	31	1,643,000	24,612,315	6.68%
February	57,000	85	28	1,596,000	24,612,315	6.48%
March	61,500	91	31	1,906,500	24,612,315	7.75%
April	70,500	105	30	2,115,000	24,612,315	8.59%
November	66,000	30	30	1,980,000	24,612,315	8.04%
December	64,000	95	31	1,984,000	24,612,315	8.06%

Permanent Counter 26-016

Month	ADT	% of ADT	# of Days	Monthly Traffic	Annual Traffic (AADT * 365)	Monthly Traffic Factor
January	122,019	93	31	3,782,589	48,027,430	7.88%
February	115,000	87	28	3,220,000	48,027,430	6.70%
March	126,339	96	31	3,916,509	48,027,430	8.15%
April	137,266	104	30	4,117,980	48,027,430	8.57%
November	129,527	98	30	3,885,810	48,027,430	8.09%
December	125,333	95	31	3,885,323	48,027,430	8.09%

Permanent Counter 26-026

Month	ADT	% of ADT	# of Days	Monthly Traffic	Annual Traffic (AADT * 365)	Monthly Traffic Factor
January	110,400	91	31	3,422,400	44,471,235	7.70%
February	115,800	95	28	3,242,400	44,471,235	7.29%
March	123,000	101	31	3,813,000	44,471,235	8.57%
April	126,162	104	30	3,784,860	44,471,235	8.51%
November	118,000	97	30	3,540,000	44,471,235	7.96%
December	113,545	93	31	3,519,895	44,471,235	7.91%

Interstate 84

Permanent counter 26-001

Month	ADT	% of ADT	# of Days	Monthly Traffic	Annual Traffic (AADT * 365)	Monthly Traffic Factor
January	19,621	71	31	608,251	10,118,165	6.01%
February	20,955	76	28	586,740	10,118,165	5.80%
March	25,254	91	31	782,874	10,118,165	7.74%
April	27,081	98	30	812,430	10,118,165	8.03%
November	25,568	92	30	767,040	10,118,165	7.58%
December	21,079	76	31	653,449	10,118,165	6.46%

Monthly traffic factors, cont'd

Interstate 205

Permanent Counter 03-016

Month	ADT	% of ADT	# of Days	Monthly Traffic	Annual Traffic (AADT * 365)	Monthly Traffic Factor
January	65,632	90	31	2,034,592	26,552,290	7.66%
February	65,361	90	28	1,830,108	26,552,290	6.89%
March	71,268	98	31	2,209,308	26,552,290	8.32%
April	72,408	100	30	2,172,240	26,552,290	8.18%
November	70,789	97	30	2,123,670	26,552,290	8.00%
December	70,277	97	31	2,178,587	26,552,290	8.20%

Permanent Counter 26-024

Month	ADT	% of ADT	# of Days	Monthly Traffic	Annual Traffic (AADT * 365)	Monthly Traffic Factor
January	82,974	80	31	2,572,194	37,695,010	6.82%
February	89,534	87	28	2,506,952	37,695,010	6.65%
March	99,319	96	31	3,078,889	37,695,010	8.17%
April	101,400	98	30	3,042,000	37,695,010	8.07%
November	107,000	104	30	3,210,000	37,695,010	8.52%
December	109,000	106	31	3,379,000	37,695,010	8.96%

US Highway 97

Permanent Counter 09-020

Month	ADT	% of ADT	# of Days	Monthly Traffic	Annual Traffic (AADT * 365)	Monthly Traffic Factor
January	14,355	73	31	445,005	7,197,070	6.18%
February	17,910	91	28	501,480	7,197,070	6.97%
March	19,086	97	31	591,666	7,197,070	8.22%
April	20,150	102	30	604,500	7,197,070	8.40%
November	18,900	96	30	567,000	7,197,070	7.88%
December	18,454	94	31	572,074	7,197,070	7.95%

Permanent Counter 09-020

Month	ADT	% of ADT	# of Days	Monthly Traffic	Annual Traffic (AADT * 365)	Monthly Traffic Factor
January	13,756	80	31	426,436	6,141,356	6.94%
February	14,831	86	28	415,268	6,141,356	6.76%
March	15,665	91	31	485,615	6,141,356	7.91%
April	16,669	97	30	500,070	6,141,356	8.14%
November	15,364	89	30	460,920	6,141,356	7.51%
December	14,668	85	31	454,708	6,141,356	7.40%

Monthly traffic factors, cont'd

US Highway 22

Permanent Counter 24-004

Month	ADT	% of ADT	# of Days	Monthly Traffic	Annual Traffic (AADT * 365)	Monthly Traffic Factor
January	17,699	85	31	548,669	7,556,230	7.26%
February	18,144	88	28	508,032	7,556,230	6.72%
March	19,323	93	31	599,013	7,556,230	7.93%
April	20,154	97	30	604,620	7,556,230	8.00%
November	19,140	92	30	574,200	7,556,230	7.60%
December	18,727	90	31	580,537	7,556,230	7.68%

Appendix C

Wear Rate Regression Results

F-MIX: I-5 South, MP 234-247

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	0.529796	DFE	53
MSE	0.009996	Root MSE	0.099981
SBC	-92.475	AIC	-94.464
Reg Rsq	0.9737	Total Rsq	0.9737
Durbin-Watson	0.6770	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.045092	0.00102	44.306	0.0001

Estimates of Autocorrelations

Lag	Covariance	Correlation	-1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	0.009811	1.000000	| |********************|
1	0.006318	0.643973	| |************* |

Preliminary MSE = 0.005742

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.64397333	0.106093	-6.070

Yule-Walker Estimates

SSE	0.300184	DFE	52
MSE	0.005773	Root MSE	0.075979
SBC	-118.628	AIC	-122.606
Reg Rsq	0.8973	Total Rsq	0.9851
Durbin-Watson	1.9960	PROB<DW	0.4991

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.043824	0.00206	21.312	0.0001

F-MIX: I-5 South, MP 294-299

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	1.097614	DFE	23
MSE	0.047722	Root MSE	0.218454
SBC	-2.75086	AIC	-3.92891
Reg Rsq	0.9748	Total Rsq	0.9748
Durbin-Watson	1.3035	PROB<DW	0.0371

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.025636	0.00086	29.813	0.0001

Estimates of Autocorrelations

Lag	Covariance	Correlation	-1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	0.045734	1.000000	| |********************|
1	0.01561	0.341311	| |******* |

Preliminary MSE = 0.040406

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.34131139	0.200398	-1.703

Yule-Walker Estimates

SSE	0.967964	DFE	22
MSE	0.043998	Root MSE	0.209758
SBC	-2.46573	AIC	-4.82184
Reg Rsq	0.9522	Total Rsq	0.9778
Durbin-Watson	1.7496	PROB<DW	0.2669

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.025615	0.00122	20.930	0.0001

F-MIX: I-84 East & West, MP 22-31

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	2.423734	DFE	86
MSE	0.028183	Root MSE	0.167878
SBC	-60.1509	AIC	-62.6168
Reg Rsq	0.9299	Total Rsq	0.9299
Durbin-Watson	0.2209	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.041661	0.00123	33.777	0.0001

Estimates of Autocorrelations

Lag	Covariance	Correlation	-1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	0.027859	1.000000	||********************|
1	0.024192	0.868377	||*****************|

Preliminary MSE = 0.006851

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.86837744	0.053788	-16.144

Yule-Walker Estimates

SSE	0.47903	DFE	85
MSE	0.005636	Root MSE	0.075071
SBC	-195.335	AIC	-200.267
Reg Rsq	0.5178	Total Rsq	0.9861
Durbin-Watson	1.7869	PROB<DW	0.1676

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.032606	0.00341	9.553	0.0001

F-MIX: I-5 South, MP 243

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	0.577287	DFE	82
MSE	0.00704	Root MSE	0.083905
SBC	-172.403	AIC	-174.821
Reg Rsq	0.9819	Total Rsq	0.9819
Durbin-Watson	2.0157	PROB<DW	0.5285

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.040620	0.000609	66.688	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0   0.006955    1.000000 |                    |********************|
 1   -0.00014   -0.019752 |                    |                    |
```

Preliminary MSE = 0.006953

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	0.01975169	0.111089	0.178

Yule-Walker Estimates

SSE	0.577057	DFE	81
MSE	0.007124	Root MSE	0.084405
SBC	-168.017	AIC	-172.854
Reg Rsq	0.9826	Total Rsq	0.9819
Durbin-Watson	1.9765	PROB<DW	0.4573

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.040622	0.000601	67.591	0.0001

F-MIX: I-5 South, MP 245

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	0.288449	DFE	80
MSE	0.003606	Root MSE	0.060047
SBC	-222.39	AIC	-224.784
Reg Rsq	0.9582	Total Rsq	0.9582
Durbin-Watson	1.9759	PROB<DW	0.4567

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.039495	0.000922	42.820	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0    0.003561     1.000000 |                    |********************|
 1   -0.00006     -0.015600 |                    |                    |
```

Preliminary MSE = 0.00356

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	0.01559979	0.112495	0.139

Yule-Walker Estimates

SSE	0.288375	DFE	79
MSE	0.00365	Root MSE	0.060418
SBC	-218.016	AIC	-222.805
Reg Rsq	0.9594	Total Rsq	0.9582
Durbin-Watson	1.9457	PROB<DW	0.4031

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.039491	0.000914	43.208	0.0001

F-Mix: US Highway 97, MP 133.5

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	2.792731	DFE	81
MSE	0.034478	Root MSE	0.185683
SBC	-40.0227	AIC	-42.4294
Reg Rsq	0.9803	Total Rsq	0.9803
Durbin-Watson	0.4378	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.051989	0.000818	63.525	0.0001

Estimates of Autocorrelations

Lag	Covariance	Correlation	-1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	0.034058	1.000000	| |********************|
1	0.026505	0.778234	| |**************** |

Preliminary MSE = 0.013431

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.77823350	0.070210	-11.084

Yule-Walker Estimates

SSE	1.091432	DFE	80
MSE	0.013643	Root MSE	0.116803
SBC	-111.727	AIC	-116.54
Reg Rsq	0.8708	Total Rsq	0.9923
Durbin-Watson	2.2557	PROB<DW	0.8796

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.051726	0.00223	23.216	0.0001

F-Mix, US Highway 97, MP 140.4

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	1.385528	DFE	81
MSE	0.017105	Root MSE	0.130787
SBC	-97.4997	AIC	-99.9064
Reg Rsq	0.9902	Total Rsq	0.9902
Durbin-Watson	0.4257	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.039425	0.000435	90.610	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0    0.016897     1.000000 |                    |********************|
 1    0.013077     0.773928 |                    |***************     |
```

Preliminary MSE = 0.006776

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.77392797	0.070802	-10.931

Yule-Walker Estimates

SSE	0.533458	DFE	80
MSE	0.006668	Root MSE	0.081659
SBC	-170.445	AIC	-175.258
Reg Rsq	0.9365	Total Rsq	0.9962
Durbin-Watson	2.5676	PROB<DW	0.9958

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.039651	0.00115	34.347	0.0001

B-Mix: I5 North, MP 234-244

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	1.171008	DFE	50
MSE	0.02342	Root MSE	0.153036
SBC	-43.8084	AIC	-45.7403
Reg Rsq	0.9692	Total Rsq	0.9692
Durbin-Watson	0.9497	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.030054	0.000758	39.642	0.0001

Estimates of Autocorrelations

Lag	Covariance	Correlation	-1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	0.022961	1.000000	| |********************|
1	0.010411	0.453437	| |********* |

Preliminary MSE = 0.01824

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.45343749	0.127327	-3.561

Yule-Walker Estimates

SSE	0.895402	DFE	49
MSE	0.018274	Root MSE	0.13518
SBC	-53.3322	AIC	-57.1958
Reg Rsq	0.9259	Total Rsq	0.9764
Durbin-Watson	1.8588	PROB<DW	0.3062

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.029896	0.00121	24.738	0.0001

B-MIX: I5 North, MP 244-249

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	0.518894	DFE	26
MSE	0.019957	Root MSE	0.141271
SBC	-26.7826	AIC	-28.0784
Reg Rsq	0.9378	Total Rsq	0.9378
Durbin-Watson	0.7496	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.019304	0.000975	19.792	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0    0.019218     1.000000 |                    |********************|
 1    0.006087     0.316729 |                    |******              |
```

Preliminary MSE = 0.01729

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.31672920	0.189703	-1.670

Yule-Walker Estimates

SSE	0.433619	DFE	25
MSE	0.017345	Root MSE	0.131699
SBC	-28.2285	AIC	-30.8201
Reg Rsq	0.9001	Total Rsq	0.9480
Durbin-Watson	1.2014	PROB<DW	0.0143

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.019635	0.00131	15.010	0.0001

B-MIX: I-84 East & West, MP 17-22

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	1.089715	DFE	48
MSE	0.022702	Root MSE	0.150673
SBC	-43.5415	AIC	-45.4333
Reg Rsq	0.9671	Total Rsq	0.9671
Durbin-Watson	1.0847	PROB<DW	0.0003

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.035231	0.000938	37.558	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0   0.022239    1.000000 |                    |********************|
 1   0.008566    0.385189 |                    |********            |
```

Preliminary MSE = 0.018939

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.38518859	0.134610	-2.862

Yule-Walker Estimates

SSE	0.903369	DFE	47
MSE	0.019221	Root MSE	0.138638
SBC	-48.6786	AIC	-52.4622
Reg Rsq	0.9312	Total Rsq	0.9727
Durbin-Watson	1.7207	PROB<DW	0.1618

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.034881	0.00138	25.214	0.0001

B-MIX: I-5 North, MP 242.75

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	5.384096	DFE	81
MSE	0.06647	Root MSE	0.257818
SBC	13.80451	AIC	11.39779
Reg Rsq	0.9515	Total Rsq	0.9515
Durbin-Watson	0.2886	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.040359	0.00101	39.869	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
 0    0.06566     1.000000 |                    |********************|
 1    0.055691    0.848182 |                    |*****************   |
 2    0.051014    0.776946 |                    |****************    |
 3    0.046238    0.704201 |                    |**************      |
 4    0.042438    0.646329 |                    |*************       |
 5    0.0434      0.660987 |                    |*************       |
```

Preliminary MSE = 0.016374

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.66083352	0.110568	-5.977
2	-0.18227884	0.132969	-1.371
3	0.04465320	0.134505	0.332
4	0.14860228	0.132969	1.118
5	-0.26624530	0.110568	-2.408

Yule-Walker Estimates

SSE	1.267602	DFE	76
MSE	0.016679	Root MSE	0.129147
SBC	-81.0308	AIC	-95.4711
Reg Rsq	0.4581	Total Rsq	0.9886
Durbin-Watson	2.0078	PROB<DW	0.5210

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.039914	0.00498	8.016	0.0001

B-MIX: US Highway 22, MP 3

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	1.610899	DFE	81
MSE	0.019888	Root MSE	0.141024
SBC	-85.1413	AIC	-87.5481
Reg Rsq	0.9838	Total Rsq	0.9838
Durbin-Watson	0.7760	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.057482	0.00082	70.085	0.0001

Estimates of Autocorrelations

Lag	Covariance	Correlation	-1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	0.019645	1.000000	| |********************|
1	0.011921	0.606825	| |************ |

Preliminary MSE = 0.012411

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.60682488	0.088865	-6.829

Yule-Walker Estimates

SSE	1.011402	DFE	80
MSE	0.012643	Root MSE	0.112439
SBC	-118.443	AIC	-123.256
Reg Rsq	0.9390	Total Rsq	0.9898
Durbin-Watson	2.3611	PROB<DW	0.9511

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.057308	0.00163	35.098	0.0001

B-MIX: I-84 East, MP 20

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	1.497511	DFE	81
MSE	0.018488	Root MSE	0.13597
SBC	-91.1264	AIC	-93.5331
Reg Rsq	0.9770	Total Rsq	0.9770
Durbin-Watson	0.4412	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.035704	0.000608	58.693	0.0001

Estimates of Autocorrelations

Lag	Covariance	Correlation	-1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	0.018262	1.000000	| |********************|
1	0.013927	0.762612	| |*************** |

Preliminary MSE = 0.007641

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.76261198	0.072321	-10.545

Yule-Walker Estimates

SSE	0.597349	DFE	80
MSE	0.007467	Root MSE	0.086411
SBC	-161.211	AIC	-166.025
Reg Rsq	0.8668	Total Rsq	0.9908
Durbin-Watson	2.3572	PROB<DW	0.9497

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.035778	0.00157	22.814	0.0001

PCC: I-5 North, MP 259-280

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	0.634228	DFE	101
MSE	0.006279	Root MSE	0.079243
SBC	-224.104	AIC	-226.729
Reg Rsq	0.9907	Total Rsq	0.9907
Durbin-Watson	0.8430	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.010944	0.000105	103.952	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0   0.006218    1.000000 |                    |********************|
 1   0.003493    0.561805 |                    |***********         |
```

Preliminary MSE = 0.004255

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.56180480	0.082727	-6.791

Yule-Walker Estimates

SSE	0.427369	DFE	100
MSE	0.004274	Root MSE	0.065373
SBC	-259.366	AIC	-264.616
Reg Rsq	0.9689	Total Rsq	0.9938
Durbin-Watson	1.9707	PROB<DW	0.4413

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.010948	0.000196	55.827	0.0001

PCC: I-5 South, MP 259-294

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	12.06857	DFE	170
MSE	0.070992	Root MSE	0.266442
SBC	37.08752	AIC	33.94585
Reg Rsq	0.9150	Total Rsq	0.9150
Durbin-Watson	0.2569	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.008859	0.000207	42.776	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0    0.070576     1.000000 |                    |********************|
 1    0.057521     0.815010 |                    |****************    |
```

Preliminary MSE = 0.023697

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.81501047	0.044573	-18.285

Yule-Walker Estimates

SSE	3.024746	DFE	169
MSE	0.017898	Root MSE	0.133783
SBC	-193.305	AIC	-199.589
Reg Rsq	0.5704	Total Rsq	0.9787
Durbin-Watson	1.8677	PROB<DW	0.1971

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.007548	0.000504	14.981	0.0001

PCC: I-5 North, MP 262

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	0.310497	DFE	81
MSE	0.003833	Root MSE	0.061914
SBC	-220.144	AIC	-222.551
Reg Rsq	0.9924	Total Rsq	0.9924
Durbin-Watson	1.8595	PROB<DW	0.2615

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.009950	0.000097	102.930	0.0001

Estimates of Autocorrelations

Lag	Covariance	Correlation	-1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	0.003787	1.000000	| |********************|
1	0.000263	0.069427	| |* |

Preliminary MSE = 0.003768

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.06942695	0.111534	-0.622

Yule-Walker Estimates

SSE	0.308998	DFE	80
MSE	0.003862	Root MSE	0.062149
SBC	-216.129	AIC	-220.943
Reg Rsq	0.9913	Total Rsq	0.9924
Durbin-Watson	1.9915	PROB<DW	0.4846

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.009950	0.000104	95.504	0.0001

PCC: I-5 North, MP 278

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	0.347151	DFE	81
MSE	0.004286	Root MSE	0.065466
SBC	-210.994	AIC	-213.401
Reg Rsq	0.9922	Total Rsq	0.9922
Durbin-Watson	0.9666	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.009728	0.000096	101.238	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0   0.004234    1.000000 |                    |********************|
 1   0.002002    0.472814 |                    |*********           |
```

Preliminary MSE = 0.003287

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.47281410	0.098517	-4.799

Yule-Walker Estimates

SSE	0.262615	DFE	80
MSE	0.003283	Root MSE	0.057295
SBC	-229.218	AIC	-234.031
Reg Rsq	0.9793	Total Rsq	0.9941
Durbin-Watson	2.1853	PROB<DW	0.8007

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.009698	0.000158	61.455	0.0001

PCC: I-5 South, MP 287.5

Autoreg Procedure

```
Dependent Variable = RUT

                    Ordinary Least Squares Estimates

               SSE          0.659273    DFE             81
               MSE          0.008139    Root MSE   0.090217
               SBC          -158.401    AIC        -160.808
               Reg Rsq        0.9924    Total Rsq    0.9924
               Durbin-Watson  1.5129    PROB<DW      0.0123

NOTE: No intercept term is used. R-squares are redefined.


            Variable    DF     B Value   Std Error  t Ratio Approx Prob

            SPLIFE       1    0.007664   0.000075   102.618      0.0001


                    Estimates of Autocorrelations

          Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

           0    0.00804     1.000000 |                    |********************|
           1    0.00185     0.230161 |                    |*****               |


                    Preliminary MSE = 0.007614

               Estimates of the Autoregressive Parameters

               Lag    Coefficient      Std Error       t Ratio
                 1    -0.23016085       0.108802        -2.115


                    Yule-Walker Estimates

               SSE          0.623413    DFE             80
               MSE          0.007793    Root MSE   0.088276
               SBC          -158.526    AIC        -163.339
               Reg Rsq        0.9880    Total Rsq    0.9928
               Durbin-Watson  2.0294    PROB<DW      0.5532

NOTE: No intercept term is used. R-squares are redefined.

            Variable    DF     B Value   Std Error  t Ratio Approx Prob

            SPLIFE       1    0.007665   0.000095    81.036      0.0001
```

PCC: I-205 North, MP 0-25

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	2.976082	DFE	119
MSE	0.025009	Root MSE	0.158143
SBC	-98.2933	AIC	-101.081
Reg Rsq	0.9713	Total Rsq	0.9713
Durbin-Watson	0.8171	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.008672	0.000137	63.422	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0   0.024801    1.000000 |                    |********************|
 1   0.014392    0.580302 |                    |************        |
```

Preliminary MSE = 0.016449

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.58030182	0.074972	-7.740

Yule-Walker Estimates

SSE	1.950784	DFE	118
MSE	0.016532	Root MSE	0.128577
SBC	-143.78	AIC	-149.355
Reg Rsq	0.9023	Total Rsq	0.9812
Durbin-Watson	2.1044	PROB<DW	0.7176

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.008617	0.000261	33.004	0.0001

PCC: I-205 South, MP 0-25

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	2.662388	DFE	124
MSE	0.021471	Root MSE	0.146529
SBC	-121.573	AIC	-124.402
Reg Rsq	0.9744	Total Rsq	0.9744
Durbin-Watson	1.0073	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.008406	0.000122	68.663	0.0001

Estimates of Autocorrelations

```
Lag  Covariance  Correlation -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

 0    0.021299    1.000000 |                    |********************|
 1    0.010379    0.487284 |                    |**********          |
```

Preliminary MSE = 0.016242

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.48728395	0.078738	-6.189

Yule-Walker Estimates

SSE	2.017506	DFE	123
MSE	0.016402	Root MSE	0.128072
SBC	-151.144	AIC	-156.801
Reg Rsq	0.9298	Total Rsq	0.9806
Durbin-Watson	2.0944	PROB<DW	0.7020

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.008350	0.000207	40.353	0.0001

PCC: I-205 North, MP 12

Autoreg Procedure

Dependent Variable = RUT

Ordinary Least Squares Estimates

SSE	1.011937	DFE	81
MSE	0.012493	Root MSE	0.111772
SBC	-123.265	AIC	-125.672
Reg Rsq	0.9912	Total Rsq	0.9912
Durbin-Watson	0.6598	PROB<DW	0.0001

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.008292	0.000087	95.420	0.0001

Estimates of Autocorrelations

Lag	Covariance	Correlation	-1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1
0	0.012341	1.000000	| |********************|
1	0.007664	0.621033	| |************ |

Preliminary MSE = 0.007581

Estimates of the Autoregressive Parameters

Lag	Coefficient	Std Error	t Ratio
1	-0.62103287	0.087630	-7.087

Yule-Walker Estimates

SSE	0.583316	DFE	80
MSE	0.007291	Root MSE	0.08539
SBC	-163.545	AIC	-168.358
Reg Rsq	0.9669	Total Rsq	0.9949
Durbin-Watson	1.9361	PROB<DW	0.3864

NOTE: No intercept term is used. R-squares are redefined.

Variable	DF	B Value	Std Error	t Ratio	Approx Prob
SPLIFE	1	0.008303	0.000172	48.335	0.0001

Appendix D

High and Low Estimates of Total Damage Costs

STUDDED TIRE PAVEMENT DAMAGE ESTIMATE FOR 1995

		State System								County & City	
REGION	PAVEMENT TYPE	1995 GROSS VMT	ANNUAL GROWTH	% LT VEH	SEASONAL FACTOR	% STUD USE	VMT Season	IN/LN/MI DAMAGE		Vmt 39% of total	IN/LN/MI DAMAGE
1	CONCRETE	1,882,204,990	1.30%	88%	44%	16%	113,691,204	8.64		-	0.00
1	ASPHALT	4,561,505,375	1.30%	88%	44%	16%	275,529,521	62.27		248,846,038	56.24
2	CONCRETE	1,099,305,540	1.30%	85%	45%	12%	52,140,062	3.96		-	0.00
2	ASPHALT	4,461,653,055	1.30%	85%	45%	12%	211,616,204	47.83		168,631,055	38.11
3	CONCRETE	490,393,560	1.30%	84%	43%	5%	9,565,028	0.73		-	0.00
3	ASPHALT	2,329,388,390	1.30%	84%	43%	5%	45,434,255	10.27		35,163,476	7.95
4	CONCRETE	26,615,800	1.30%	81%	43%	40%	3,717,384	0.28		-	0.00
4	ASPHALT	1,931,755,930	1.30%	81%	43%	40%	269,805,067	60.98		174,875,009	39.52
5	CONCRETE	232,164,455	1.30%	78%	41%	30%	22,422,350	1.70		-	0.00
5	ASPHALT	1,337,809,315	1.30%	78%	41%	30%	129,205,069	29.20		96,942,133	21.91

DAMAGE FACTORS PER MILLION VMT

CONCRETE	0.076
ASPHALT	0.226
	0.226
	0.226
	0.226

	State System		County & City	
INCH/LANE/MILES DAMAGES	CONCRETE	15.32	CONCRETE	0.00
	ASPHALT	210.54	ASPHALT	163.73

ANNUAL DAMAGE

MITIGATING STRATEGY	REPLACE COST LN/MI	THRESHOLD (INCHES)		COST		COST
2" AC OVERLAY (PCC)	$211,200	0.75	CONCRETE	$4,313,193	CONCRETE	$0
2" AC OVERLAY	$52,800	0.75	ASPHALT	$14,821,972	ASPHALT	$11,526,412
				$19,135,165		**$11,526,412**

TOTAL COST	
CONCRETE	4,313,193
ASPHALT	26,348,384
TOTAL COST	$ 30,661,577

LOW

STUDDED TIRE PAVEMENT DAMAGE ESTIMATE FOR 1995

REGION	PAVEMENT TYPE	State System: 1995 GROSS VMT	ANNUAL GROWTH	% LT VEH.	SEASONAL FACTOR	% STUD USE	VMT Season	IN/LN/MI DAMAGE	County & City: Vmt 39% of total	IN/LN/MI DAMAGE
1	CONCRETE	1,882,204,990	1.30%	88%	44%	16%	113,691,204	12.51	-	0.00
1	ASPHALT	4,561,505,375	1.30%	88%	44%	16%	275,529,521	150.16	248,846,038	135.62
2	CONCRETE	1,099,305,540	1.30%	85%	45%	12%	52,140,062	5.74	-	0.00
2	ASPHALT	4,461,653,055	1.30%	85%	45%	12%	211,616,204	115.33	168,631,055	91.90
3	CONCRETE	490,393,560	1.30%	84%	43%	5%	9,565,028	1.05	-	0.00
3	ASPHALT	2,329,388,390	1.30%	84%	43%	5%	45,434,255	24.76	35,163,476	19.16
4	CONCRETE	26,615,800	1.30%	81%	43%	40%	3,717,384	0.41	-	0.00
4	ASPHALT	1,931,755,930	1.30%	81%	43%	40%	269,805,067	147.04	174,875,009	95.31
5	CONCRETE	232,164,455	1.30%	78%	41%	30%	22,422,350	2.47	-	0.00
5	ASPHALT	1,337,809,315	1.30%	78%	41%	30%	129,205,089	70.42	96,942,133	52.83

DAMAGE FACTORS PER MILLION VMT								
CONCRETE	0.110							
ASPHALT	0.545							
	0.545	INCH/LANE/MILES DAMAGES	CONCRETE	22.17	CONCRETE	0.00		
	0.545		ASPHALT	507.72	ASPHALT	394.83		
	0.545							

ANNUAL DAMAGE

MITIGATING STRATEGY	REPLACE COST LN/MI	THRESHOLD (INCHES)		COST		COST
2" AC OVERLAY (PCC)	$211,200	0.75	CONCRETE	$6,242,780	CONCRETE	$0
2" AC OVERLAY	$52,800	0.75	ASPHALT	$35,743,250	ASPHALT	$27,795,993
				$41,986,030		**$27,795,993**

	TOTAL COST
CONCRETE	6,242,780
ASPHALT	63,539,244
TOTAL COST	**$ 69,782,024**

HIGH

Appendix E: Regional Factors for Passenger Vehicles and Seasonal Traffic Volumes.

Monthly factors represent average daily traffic for the month relative to annual average daily traffic
Seasonal factors represent the annual traffic volume occurring during the six month studded tire season.

County	**County Avg.**	1	1	1	1	1
Station Number		01-001	01-007	01-010	01-011	12
HWY		US30	ORE203	ORE86	I84	ORE7
% Pas Veh	**66%**	0.869	95.1	90.8	56.3	84.9
Jan		80	76	71	71	66
Feb		88	78	74	76	67
Mar		93	80	86	93	74
Apr		102	90	94	96	86
Nov		91	89	76	90	84
Dec		87	82	71	78	66
Seasonal	**41%**	45%	41%	39%	42%	37%

County		2	2	2
Station Number		3	5	7
HWY		ORE34	ORE223	ORE99W
% Pas Veh	**87%**	89.7	84.9	86.4
Jan		89	87	86
Feb		90	90	92
Mar		92	97	97
Apr		96	98	99
Nov		96	100	98
Dec		88	85	88
Seasonal	**46%**	46%	46%	47%

County		3	3	3	3
Station Number		11	13	14	16
HWY		I5	ORE213	ORE211	I205
% Pas Veh	**89%**	85.8	91.3	90	90.6
Jan		79	84	85	90
Feb		85	88	88	90
Mar		91	95	95	98
Apr		105	100	99	100
Nov		98	96	91	97
Dec		95	95	84	97
Seasonal	**46%**	46%	47%	45%	48%

County		4	
Station Number		1	10

HWY		US101	ore202
% Pas Veh	**89%**	93.6	84.6
Jan		75	85
Feb		84	79
Mar		95	84
Apr		100	85
Nov		85	125
Dec		76	77
Seasonal	**44%**	43%	45%

County		5
Station Number		6
HWY		us30
% Pas Veh	**89%**	89.3
Jan		82
Feb		87
Mar		93
Apr		101
Nov		90
Dec	**45%**	45%
Seasonal		44.9167

County		6	
Station Number		1	4
HWY		us101	us101
% Pas Veh	**86%**	86.6	85.6
Jan		73	75
Feb		82	86
Mar		89	88
Apr		93	95
Nov		88	90
Dec		82	89
Seasonal	**43%**	42%	44%

County		7
Station Number		1
HWY		us26
% Pas Veh	**90%**	89.5
Jan		70
Feb		75
Mar		80
Apr		90
Nov		99
Dec		75
Seasonal	**41%**	41%

County		8
Station Number		5
HWY		us101
% Pas Veh	93%	93.1
Jan		85
Feb		91
Mar		86
Apr		95
Nov		90
Dec		86
Seasonal	44%	44%

County		9				
Station Number		3	5	11	14	20
HWY		us97	US20	Cent Dr.	us20-ore126	us97
% Pas Veh	89%	89.6	85.2	96.3	87.3	88.8
Jan		80	71	189	62	73
Feb		86	82	191	69	91
Mar		91	89	186	79	97
Apr		97	96	109	85	102
Nov		89	85	25	75	96
Dec		85	75	195	68	94
Seasonal	49%	44%	42%	75%	37%	46%

County		10			
Station Number		3	4	6	7
HWY		ore38	ore138	ore42	i5
% Pas Veh	71%	68.6	64.8	84.4	67.9
Jan		67	56	85	83
Feb		79	53	95	85
Mar		92	67	99	95
Apr		92	77	102	85
Nov		86	73	91	92
Dec		83	54	86	92
Seasonal	41%	42%	32%	47%	44%

County		11		
Station Number		4	7	8
HWY		ore206	ore19	i84
% Pas Veh	72%	93	51.8	71.7
Jan		78	99	67

Feb		77	96	72
Mar		86	101	90
Apr		99	104	93
Nov		105	91	98
Dec		86	82	77
Seasonal	**44%**	44%	48%	41%

County		12		
Station Number		3	6	9
HWY		us26	us395	us26
% Pas Veh	**79%**	82.3	86.2	68.2
Jan		68	73	59
Feb		67	66	61
Mar		77	81	75
Apr		80	87	92
Nov		97	106	88
Dec		68	62	61
Seasonal	**38%**	38%	40%	36%

County		13	
Station Number		1	3
HWY		us395	us20
% Pas Veh	**81%**	85.6	76.8
Jan		67	62
Feb		68	71
Mar		71	85
Apr		83	92
Nov		97	87
Dec		74	70
Seasonal	**39%**	38%	39%

County		14
Station Number		3
HWY		ore35
% Pas Veh	**91%**	90.5
Jan		95
Feb		83
Mar		86
Apr		78
Nov		61
Dec		79
Seasonal	**40%**	40%

County		15				
Station Number		1	2	7	11	12
HWY		i5	i5	ore66	ore239	main st.
% Pas Veh	**86%**	79	62.6	92.7	95.8	98
Jan		86	74	69	82	95
Feb		89	81	84	87	102
Mar		97	90	80	95	104
Apr		99	94	99	101	105
Nov		94	92	86	90	95
Dec		89	94	71	86	96
Seasonal	**45%**	46%	44%	41%	45%	50%

County					
Station Number	13	14	18	19	20
HWY	ore62	ore99	I5	I5	ore140
% Pas Veh	93.2	96	83.7	84.9	76.7
Jan	76	88	83	87	70
Feb	84	96	89	93	80
Mar	85	95	94	96	77
Apr	93	101	101	102	84
Nov	90	97	101	99	93
Dec	86	95	90	96	79
Seasonal	43%	48%	47%	48%	40%

County		16	
Station Number		2	6
HWY		us97/us26	us26
% Pas Veh	**87%**	86.4	87.7
Jan		77	76
Feb		85	82
Mar		94	91
Apr		100	95
Nov		89	87
Dec		80	82
Seasonal	**43%**	44%	43%

County		17		
Station Number		1	3	6
HWY		I5	us199	cnty rd
% Pas Veh	**86%**	82	84.9	91.2
Jan		78	64	90
Feb		82	76	96
Mar		92	68	97
Apr		96	88	102

Nov		97	85	97
Dec		90	75	91
Seasonal	**43%**	45%	38%	48%

County		18				
Station Number		6	17	19	20	21
HWY		us97	ore140	us97	ore39	ore62
% Pas Veh	**77%**	60.1	85.1	63	84.5	91.6
Jan		60	76	66	79	35
Feb		69	75	79	88	43
Mar		79	87	79	93	44
Apr		88	79	91	100	61
Nov		86	88	97	95	54
Dec		79	75	84	86	39
Seasonal	**38%**	38%	40%	41%	45%	23%

County		19		
Station Number		4	8	10
HWY		us395	us395	ore31
% Pas Veh	**80%**	79.1	82.7	78
Jan		68	69	63
Feb		77	79	68
Mar		90	84	80
Apr		95	93	87
Nov		74	90	124
Dec		54	74	84
Seasonal	**40%**	38%	41%	42%

County		20						
Station Number		3	4	5	8	10	17	23
HWY		ore99	ore36	ore126	I105	ore126	ore58	Terri. Hwy
% Pas Veh	**91%**	97.1	91.6	88.4	94	84.1	59.5	93.3
Jan		86	83	84	93	69	74	80
Feb		98	86	87	97	72	77	86
Mar		99	93	94	99	82	82	93
Apr		103	94	94	100	91	84	96
Nov		97	96	86	100	83	80	94
Dec		88	87	84	98	71	65	89
Seasonal	**44%**	48%	45%	44%	49%	39%	39%	45%

County		21
Station Number		6
HWY		us20

% Pas Veh	**75%**	75.2
Jan		80
Feb		88
Mar		97
Apr		95
Nov		88
Dec		72
Seasonal	**43%**	43%

County Station Number		22 10	12	13	16
HWY		ore226	ore99e	us20	I5
% Pas Veh	**86%**	93.6	83.4	91.3	74.3
Jan		88	85	89	73
Feb		91	89	93	79
Mar		98	97	94	98
Apr		100	98	98	96
Nov		93	91	92	100
Dec		93	88	91	92
Seasonal	**46%**	47%	46%	46%	45%

County Station Number		23 6	12	13	14	16
HWY		US20/us2 6	us95	us20	I84	I84
% Pas Veh	**65%**	83.6	56	64.4	71.2	49.1
Jan		80	63	57	92	70
Feb		86	72	65	83	76
Mar		93	98	82	94	92
Apr		103	114	88	96	97
Nov		88	92	85	86	100
Dec		84	75	66	85	86
Seasonal	**42%**	45%	43%	37%	45%	43%

County Station Number		24 1	4	10	13	14	16	18	20
HWY		ORE99e	ore22	Cnty Rd.	ORE22	ore22	W_H Hwy	Ctr St.	ORE219
% Pas Veh	**91%**	94.8	93.2	90.6	81.8	95.2	88.7	98	84.7
Jan		86	85	82	62	92	98	95	76
Feb		90	88	85	69	94	99	97	81
Mar		94	93	91	84	97	98	10	91
Apr		100	97	99	88	101	104	104	98
Nov		91	92	89	78	97	97	99	85
Dec		87	90	83	65	101	98	105	81
Seasonal	**44%**	46%	45%	44%	37%	49%	50%	43%	43%

County		25
Station Number		7
HWY		ORE74
% Pas Veh	**90%**	89.8
Jan		86
Feb		87
Mar		96
Apr		97
Nov		99
Dec		93
Seasonal	**47%**	47%

County		26				
Station Number		1	2	3	4	5
HWY		I84	us26	us26	I5	I405
% Pas Veh	**91%**	75.5	96.1	96.1	91.5	93.3
Jan		71	94	93	93	92
Feb		76	88	91	93	99
Mar		91	100	97	100	100
Apr		98	102	100	101	103
Nov		92	98	95	98	97
Dec		76	97	99	97	92
Seasonal	**47%**	42%	48%	48%	49%	49%

County		26					
Station Number	12	13	16	19	24	26	27
HWY	Hist. Col	I84	I5	I5	I205	I5	I405
% Pas Veh	96.4	94.7	93	89.7	92.1	94.5	88.3
Jan	49	91	93	94	80	91	99
Feb	64	87	87	93	87	95	92
Mar	81	100	96	100	96	101	102
Apr	100	102	104	101	98	104	108
Nov	56	99	98	97	104	97	95
Dec	46	99	95	94	106	93	93
Seasonal	41%	48%	48%	48%	48%	48%	49%

County		27
Station Number		1
HWY		ore18
% Pas Veh	**91%**	91.4
Jan		67
Feb		76
Mar		88
Apr		87

Nov		112
Dec		96
Seasonal	**44%**	44%

County		28
Station Number		1
HWY		ur97
% Pas Veh	**69%**	69.3
Jan		69
Feb		77
Mar		94
Apr		100
Nov		87
Dec		75
Seasonal	**42%**	42%

County		29
Station Number		1
HWY		US101
% Pas Veh	**90%**	89.9
Jan		33
Feb		79
Mar		102
Apr		99
Nov		66
Dec		66
Seasonal	**37%**	37%

County		30						
Station Number		2	4	7	12	16	21	25
HWY		US730	I84	US395	ore204	Athena	ORE11	I82
% Pas Veh	**78%**	72.1	69.9	82	82.8	83.7	94	70.7
Jan		68	42	73	87	81	82	72
Feb		89	45	74	84	93	88	79
Mar		90	52	80	69	94	97	96
Apr		92	53	89	72	101	104	99
Nov		94	53	107	90	90	93	95
Dec		80	46	65	82	83	92	83
Seasonal	**40%**	43%	24%	41%	40%	45%	46%	44%

County		31
Station Number		5
HWY		ORE82

% Pas Veh	**85%**	84.5	
Jan		72	
Feb		75	
Mar		88	
Apr		90	
Nov		93	
Dec		78	
Seasonal	**41%**	41%	

County		33	
Station		1	5
Number			
HWY		I84	US197
% Pas Veh	**83%**	75	91.9
Jan		71	79
Feb		75	83
Mar		92	96
Apr		96	102
Nov		100	91
Dec		82	80
Seasonal	**44%**	43%	44%

County		34	
Station		1	4
Number			
HWY		US 26	ORE6
% Pas Veh	**80%**	74.4	84.9
Jan		68	68
Feb		76	70
Mar		93	86
Apr		94	88
Nov		81	89
Dec		64	65
Seasonal	**39%**	40%	39%

County		36	
Station		4	5
Number			
HWY		ORE99w	ORE99w
% Pas Veh	**89%**	93.6	83.4
Jan		90	91
Feb		91	94
Mar		97	98
Apr		99	102
Nov		101	98
Dec		97	90
Seasonal	**48%**	48%	48%

COUNTY SUMMARIES

	County	Passenger Vehicles	Seasonal Factor
REGION 1	Clackamas (3)	89%	46%
	Columbia (5)	89%	45%
	Hood River (14)	91%	40%
	Multnomah (26)	91%	47%
	Washington (34)	80%	39%
REGION 2	Benton (2)	87%	46%
	Clatsop(4)	89%	44%
	Lane(20)	91%	44%
	Lincoln (21)	75%	43%
	Linn (22)	86%	46%
	Marion (24)	91%	44%
	Polk (27)	91%	44%
	Tillamook (29)	69%	42%
	Yamhill (36)	89%	48%
REGION 3	Coos (6)	86%	43%
	Curry (8)	93%	44%
	Douglas (10)	71%	41%
	Jackson (15)	86%	45%
	Josephine (17)	86%	43%
REGION 4	Crook (7)	90%	41%
	Dsschutes (9)	89%	49%
	Gilliam (11)	72%	44%
	Jefferson (16)	87%	43%
	Klamath (18)	77%	38%
	Lake (19)	80%	40%
	Sherman (28)	69%	42%
	Wasco (33)	83%	44%
	Wheeler (35)		
REGION 5	Baker (1)	66%	41%
	Grant (12)	79%	38%
	Harney (13)	81%	39%
	Malheur (23)	65%	42%
	Morrow (25)	90%	47%
	Umatilla (30)	78%	42%
	Union (31)	85%	41%
	Wallowa (32)		

REGIONAL SUMMARIES

	Passenger Vehicles	Seasonal Factor	Effective Stud Use
Region 1	**88%**	**44%**	**15.6%**
Region 2	**85%**	**45%**	**12.4%**
Region 3	**84%**	**43%**	**5.4%**
Region 4	**81%**	**43%**	**40.1%**
Region 5	**78%**	**41%**	**30.2%**

Appendix F: Estimates of Effective Damage Costs

Mitigation costs for 1995 studded tire damage on Oregon State Highway System

Surface Inputs	Asphalt	PCC
Rut Threshold (inches)	0.75	0.75
Design Life (years)	14	30
Mitigation cost per lane mile,	$52,800	$52,800
Wear Rate: Inches / 100,000 studded tire passes	0.0545	0.011

Design life	Wear Rate
Base	High

				Cost Estimates		
Regional Inputs	Season%	Pass. Veh. %	Stud %	**Asphalt**	**PCC**	**ALL SURFACES**
Region 1	44%	88%	15.6%	$5,552,821	$2,509,170	$8,061,991
Region 2	45%	85%	12.4%	$3,292,930	$877,433	$4,170,363
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$4,625,490	$0	$4,625,490
Region 5	41%	78%	30.2%	$420,717	$0	$420,717
STATEWIDE				**$13,891,958**	**$3,386,602**	**$17,278,560**

* Mitigation strategy: asphalt overlay

Cost taken from Repair of Rutting Caused by Studded Tires, ODOT, July '95.

Includes 50% above material cost for traffic control.

Regional Inputs				Lane Mile Costs		Lane Mile Costs
	Season%	PV %	Stud %	**Asphalt**	**PCC**	**ALL SURFACES**
Region 1	44%	88%	15.6%	$5,552,821	$829,358	$6,382,179
Region 2	45%	85%	12.4%	$3,292,930	$202,500	$3,495,430
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$4,625,490	$0	$4,625,490
Region 5	41%	78%	30.2%	$420,717	$0	$420,717
STATEWIDE				**$13,891,958**	**$1,031,858**	**$14,923,816**

Mitigation costs for 1995 studded tire damage on Oregon State Highway System

Surface Inputs	Asphalt	PCC
Rut Threshold (inches)	0.75	0.75
Design Life (years)	14	30
Mitigation cost per lane mile,	$52,800	$52,800
Wear Rate: Inches / 100,000 studded tire passes	0.0386	0.0093

Design life	Wear Rate
Base	Base

Regional Inputs	Season%	Pass. Veh. %	Stud %	Cost Estimates Asphalt	PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$3,019,116	$2,121,389	$5,140,505
Region 2	45%	85%	12.4%	$1,810,814	$741,829	$2,552,643
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$2,242,845	$0	$2,242,845
Region 5	41%	78%	30.2%	$129,238	$0	$129,238
STATEWIDE				**$7,202,013**	**$2,863,218**	**$10,065,231**

* Mitigation strategy: asphalt overlay
Cost taken from Repair of Rutting Caused by Studded Tires, ODOT, July '95.
Includes 50% above material cost for traffic control.

Regional Inputs				Lane Mile Costs		Lane Mile Costs
	Season%	PV %	Stud %	Asphalt	PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$3,019,116	$663,846	$3,682,962
Region 2	45%	85%	12.4%	$1,810,814	$171,205	$1,982,018
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$2,242,845	$0	$2,242,845
Region 5	41%	78%	30.2%	$129,238	$0	$129,238
STATEWIDE				**$7,202,013**	**$835,050**	**$8,037,063**

Mitigation costs for 1995 studded tire damage on Oregon State Highway System

Surface Inputs	Asphalt	PCC
Rut Threshold (inches)	0.75	0.75
Design Life (years)	14	30
Mitigation cost per lane mile,	$52,800	$52,800
Wear Rate: Inches / 100,000 studded tire passes	0.0226	0.0076

Design life	Wear Rate
Base	Low

Regional Inputs	Season%	Pass. Veh. %	Stud %	Cost Estimates: Asphalt	Cost Estimates: PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$1,139,946	$1,733,608	$2,873,554
Region 2	45%	85%	12.4%	$481,785	$606,226	$1,088,012
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$272,375	$0	$272,375
Region 5	41%	78%	30.2%	$7,080	$0	$7,080
STATEWIDE				**$1,901,186**	**$2,339,834**	**$4,241,020**

* Mitigation strategy: asphalt overlay
Cost taken from Repair of Rutting Caused by Studded Tires, ODOT, July '95.
Includes 50% above material cost for traffic control.

Regional Inputs	Season%	PV %	Stud %	Lane Mile Costs: Asphalt	Lane Mile Costs: PCC	Lane Mile Costs ALL SURFACES
Region 1	44%	88%	15.6%	$1,139,946	$515,391	$1,655,337
Region 2	45%	85%	12.4%	$481,785	$139,909	$621,694
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$272,375	$0	$272,375
Region 5	41%	78%	30.2%	$7,080	$0	$7,080
STATEWIDE				**$1,901,186**	**$655,300**	**$2,556,487**

Mitigation costs for 1995 studded tire damage on Oregon State Highway System

Surface Inputs	Asphalt	PCC
Rut Threshold (inches)	0.75	0.75
Design Life (years)	12	25
Mitigation cost per lane mile,	$52,800	$52,800
Wear Rate: Inches / 100,000 studded tire passes	0.0386	0.0093

Design life	Wear Rate
Short	Base

Regional Inputs	Season%	Pass. Veh. %	Stud %	Cost Estimates Asphalt	PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$2,817,844	$2,121,389	$4,939,233
Region 2	45%	85%	12.4%	$1,458,831	$741,829	$2,200,660
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$1,762,170	$0	$1,762,170
Region 5	41%	78%	30.2%	$95,973	$0	$95,973
STATEWIDE				**$6,134,818**	**$2,863,218**	**$8,998,036**

* Mitigation strategy: asphalt overlay
Cost taken from Repair of Rutting Caused by Studded Tires, ODOT, July '95.
Includes 50% above material cost for traffic control.

Regional Inputs				Lane Mile Costs		Lane Mile Costs
	Season%	PV %	Stud %	Asphalt	PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$2,817,844	$642,042	$3,459,885
Region 2	45%	85%	12.4%	$1,458,831	$171,205	$1,630,035
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$1,762,170	$0	$1,762,170
Region 5	41%	78%	30.2%	$95,973	$0	$95,973
STATEWIDE				**$6,134,818**	**$813,246**	**$6,948,064**

Mitigation costs for 1995 studded tire damage on Oregon State Highway System

Surface Inputs	Asphalt	PCC
Rut Threshold (inches)	0.75	0.75
Design Life (years)	12	25
Mitigation cost per lane mile,	$52,800	$52,800
Wear Rate: Inches / 100,000 studded tire passes	0.0545	0.011

Design life	Wear Rate
Short	High

				Cost Estimates		
Regional Inputs	Season%	Pass. Veh. %	Stud %	**Asphalt**	**PCC**	**ALL SURFACES**
Region 1	44%	88%	15.6%	$4,832,658	$2,509,170	$7,341,828
Region 2	45%	85%	12.4%	$2,918,365	$877,433	$3,795,797
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$4,306,004	$0	$4,306,004
Region 5	41%	78%	30.2%	$277,372	$0	$277,372
STATEWIDE				**$12,334,399**	**$3,386,602**	**$15,721,001**

* Mitigation strategy: asphalt overlay
Cost taken from Repair of Rutting Caused by Studded Tires, ODOT, July '95.
Includes 50% above material cost for traffic control.

Regional Inputs				**Lane Mile Costs**		**Lane Mile Costs**
	Season%	PV %	Stud %	**Asphalt**	**PCC**	**ALL SURFACES**
Region 1	44%	88%	15.6%	$4,832,658	$785,194	$5,617,852
Region 2	45%	85%	12.4%	$2,918,365	$202,500	$3,120,865
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$4,306,004	$0	$4,306,004
Region 5	41%	78%	30.2%	$277,372	$0	$277,372
STATEWIDE				**$12,334,399**	**$987,694**	**$13,322,092**

Mitigation costs for 1995 studded tire damage on Oregon State Highway System

Surface Inputs	Asphalt	PCC
Rut Threshold (inches)	0.75	0.75
Design Life (years)	12	25
Mitigation cost per lane mile,	$52,800	$52,800
Wear Rate: Inches / 100,000 studded tire passes	0.0226	0.0076

Design life	Wear Rate
Short	Low

Regional Inputs	Season%	Pass. Veh. %	Stud %	Cost Estimates: Asphalt	Cost Estimates: PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$977,162	$1,733,608	$2,710,770
Region 2	45%	85%	12.4%	$319,388	$522,988	$842,377
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$176,602	$0	$176,602
Region 5	41%	78%	30.2%	$0	$0	$0
STATEWIDE				**$1,473,153**	**$2,256,597**	**$3,729,749**

* Mitigation strategy: asphalt overlay

Cost taken from Repair of Rutting Caused by Studded Tires, ODOT, July '95.

Includes 50% above material cost for traffic control.

Regional Inputs				Lane Mile Costs		Lane Mile Costs
	Season%	PV %	Stud %	Asphalt	PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$977,162	$454,075	$1,431,238
Region 2	45%	85%	12.4%	$319,388	$120,699	$440,087
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$176,602	$0	$176,602
Region 5	41%	78%	30.2%	$0	$0	$0
STATEWIDE				**$1,473,153**	**$574,774**	**$2,047,927**

Mitigation costs for 1995 studded tire damage on Oregon State Highway System

Surface Inputs	Asphalt	PCC
Rut Threshold (inches)	0.75	0.75
Design Life (years)	16	35
Mitigation cost per lane mile,	$52,800	$52,800
Wear Rate: Inches / 100,000 studded tire passes	0.0386	0.0093

Design life	Wear Rate
Long	Base

Regional Inputs	Season%	Pass. Veh. %	Stud %	Cost Estimates Asphalt	PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$3,322,708	$2,121,389	$5,444,097
Region 2	45%	85%	12.4%	$1,973,943	$741,829	$2,715,772
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$2,715,304	$0	$2,715,304
Region 5	41%	78%	30.2%	$150,340	$0	$150,340
STATEWIDE				**$8,162,295**	**$2,863,218**	**$11,025,514**

* Mitigation strategy: asphalt overlay
Cost taken from Repair of Rutting Caused by Studded Tires, ODOT, July '95.
Includes 50% above material cost for traffic control.

Regional Inputs				Lane Mile Costs		Lane Mile Costs
	Season%	PV %	Stud %	Asphalt	PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$3,322,708	$691,013	$4,013,722
Region 2	45%	85%	12.4%	$1,973,943	$171,205	$2,145,148
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$2,715,304	$0	$2,715,304
Region 5	41%	78%	30.2%	$150,340	$0	$150,340
STATEWIDE				**$8,162,295**	**$862,218**	**$9,024,513**

Mitigation costs for 1995 studded tire damage on Oregon State Highway System

Surface Inputs	Asphalt	PCC
Rut Threshold (inches)	0.75	0.75
Design Life (years)	16	35
Mitigation cost per lane mile,	$52,800	$52,800
Wear Rate: Inches / 100,000 studded tire passes	0.0545	0.011

Design life	**Wear Rate**
Long	**High**

Regional Inputs	Season%	Pass. Veh. %	Stud %	Cost Estimates: Asphalt	Cost Estimates: PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$5,843,736	$2,509,170	$8,352,906
Region 2	45%	85%	12.4%	$3,612,451	$957,427	$4,569,877
Region 3	43%	84%	5.4%	$10,488	$0	$10,488
Region 4	43%	81%	40.1%	$4,808,701	$0	$4,808,701
Region 5	41%	78%	30.2%	$585,792	$0	$585,792
STATEWIDE				**$14,861,168**	**$3,466,596**	**$18,327,764**

* Mitigation strategy: asphalt overlay

Cost taken from Repair of Rutting Caused by Studded Tires, ODOT, July '95.

Includes 50% above material cost for traffic control.

Regional Inputs				Lane Mile Costs		Lane Mile Costs
	Season%	PV %	Stud %	Asphalt	PCC	ALL SURFACES
Region 1	44%	88%	15.6%	$5,843,736	$884,776	$6,728,512
Region 2	45%	85%	12.4%	$3,612,451	$226,501	$3,838,951
Region 3	43%	84%	5.4%	$10,488	$0	$10,488
Region 4	43%	81%	40.1%	$4,808,701	$0	$4,808,701
Region 5	41%	78%	30.2%	$585,792	$0	$585,792
STATEWIDE				**$14,861,168**	**$1,111,276**	**$15,972,444**

Mitigation costs for 1995 studded tire damage on Oregon State Highway System

Surface Inputs	Asphalt	PCC
Rut Threshold (inches)	0.75	0.75
Design Life (years)	16	35
Mitigation cost per lane mile,	$52,800	$52,800
Wear Rate: Inches / 100,000 studded tire passes	0.0226	0.0076

Design life	Wear Rate
Long	Low

				Cost Estimates		
Regional Inputs	Season%	Pass. Veh. %	Stud %	**Asphalt**	**PCC**	**ALL SURFACES**
Region 1	44%	88%	15.6%	$1,347,757	$1,733,608	$3,081,366
Region 2	45%	85%	12.4%	$541,532	$606,226	$1,147,758
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$722,410	$0	$722,410
Region 5	41%	78%	30.2%	$17,295	$0	$17,295
STATEWIDE				**$2,628,995**	**$2,339,834**	**$4,968,829**

* Mitigation strategy: asphalt overlay

Cost taken from Repair of Rutting Caused by Studded Tires, ODOT, July '95.

Includes 50% above material cost for traffic control.

Regional Inputs				**Lane Mile Costs**		**Lane Mile Costs**
	Season%	PV %	Stud %	**Asphalt**	**PCC**	**ALL SURFACES**
Region 1	44%	88%	15.6%	$1,347,757	$536,381	$1,884,138
Region 2	45%	85%	12.4%	$541,532	$139,909	$681,441
Region 3	43%	84%	5.4%	$0	$0	$0
Region 4	43%	81%	40.1%	$722,410	$0	$722,410
Region 5	41%	78%	30.2%	$17,295	$0	$17,295
STATEWIDE				**$2,628,995**	**$676,290**	**$3,305,285**

Appendix G: Estimates of Annual Expenditure Costs For Long and Intermediate Design Life

Expenditure Projections for Repair of Studded Tire Damage

Assuming reconstruction when pavement reaches design life

Variable Surface Inputs

	AC	PCC
Design Life	12	25
Wear Rate	0.0545	0.011

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	1,030,656	459,360	0	0	0	**1,490,016**
1996	496,320	817,872	0	707,520	0	**2,021,712**
1997	2,521,728	1,118,832	0	957,264	0	**4,597,824**
1998	3,160,080	882,816	0	1,418,208	602,448	**6,063,552**
1999	4,269,408	1,157,376	0	1,556,016	10,560	**6,993,360**
2000	2,842,752	2,867,040	0	3,674,880	270,864	**9,655,536**
2001	6,366,624	2,204,928	0	6,734,112	79,728	**15,385,392**
2002	6,371,904	3,731,904	0	5,863,968	21,120	**15,988,896**
2003	4,551,360	4,786,320	0	6,619,536	364,848	**16,322,064**
2004	5,348,640	3,035,472	163,152	4,177,536	628,848	**13,353,648**
2005	7,456,944	3,819,552	0	5,625,312	2,333,232	**19,235,040**
11-year	**44,416,416**	**24,881,472**	**163,152**	**37,334,352**	**4,311,648**	**$ 111,107,040**

Studded tire growth

1996-2005	2.50%
1986-1995	8.45%
1976-1985	0.00%
1968-1975	0.00%

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	3,983,102	0	0	0	0	**3,983,102**
1996	2,949,005	0	0	0	0	**2,949,005**
1997	876,480	0	0	0	0	**876,480**
1998	3,894,985	0	0	0	0	**3,894,985**
1999	1,812,506	0	0	0	0	**1,812,506**
2000	1,692,717	0	0	0	0	**1,692,717**
2001	2,450,152	0	0	0	0	**2,450,152**
2002	1,185,888	0	0	0	0	**1,185,888**
2003	3,871,416	0	0	0	0	**3,871,416**
2004	5,695,189	0	0	0	0	**5,695,189**
2005	3,928,953	0	0	0	0	**3,928,953**
11-year	**32,340,393**	**0**	**0**	**0**	**0**	**$ 32,340,393**

AC and PCC Total	
Projected Repair Totals	
1995	**$ 5,473,118**
1996	**$ 4,970,717**
1997	**$ 5,474,304**
1998	**$ 9,958,537**
1999	**$ 8,805,866**
2000	**$ 11,348,253**
2001	**$ 17,835,544**
2002	**$ 17,174,784**
2003	**$ 20,193,480**
2004	**$ 19,048,837**
2005	**$ 23,163,993**
total	**$ 143,447,433**

BASE

Expenditure Projections for Repair of Studded Tire Damage

Assuming reconstruction when pavement reaches design life

Variable Surface Inputs

	AC	PCC
Design Life	12	25
Wear Rate	0.0386	0.0093

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	1,030,656	0	0	0	0	**1,030,656**
1996	34,848	294,624	0	0	0	**329,472**
1997	591,888	476,784	0	350,064	0	**1,418,736**
1998	1,999,008	505,824	0	792,000	0	**3,296,832**
1999	3,198,096	1,207,008	0	281,424	0	**4,686,528**
2000	1,279,344	1,099,824	0	1,449,360	0	**3,828,528**
2001	3,525,984	1,573,440	0	1,094,016	10,560	**6,204,000**
2002	2,422,464	1,058,112	0	3,460,512	164,208	**7,105,296**
2003	4,015,968	985,776	0	4,090,416	79,728	**9,171,888**
2004	3,728,208	3,444,672	0	3,943,632	0	**11,116,512**
2005	4,105,728	3,855,456	0	3,878,160	385,968	**12,225,312**
11-year	**25,932,192**	**14,501,520**	**0**	**19,339,584**	**#####**	**$ 60,413,760**

Studded tire growth

1996-2005	2.50%
1986-1995	8.45%
1976-1985	0.00%
1968-1975	0.00%

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	2,576,090	0	0	0	0	**2,576,090**
1996	1,221,698	0	0	0	0	**1,221,698**
1997	3,134,319	0	0	0	0	**3,134,319**
1998	281,952	0	0	0	0	**281,952**
1999	680,592	0	0	0	0	**680,592**
2000	3,343,061	0	0	0	0	**3,343,061**
2001	680,592	0	0	0	0	**680,592**
2002	2,921,078	0	0	0	0	**2,921,078**
2003	680,592	0	0	0	0	**680,592**
2004	3,544,056	0	0	0	0	**3,544,056**
2005	5,341,957	0	0	0	0	**5,341,957**
11-year	**24,405,986**	**0**	**0**	**0**	**0**	**$ 24,405,986**

AC and PCC Total Projected Repair Totals	
1995	**$ 3,606,746**
1996	**$ 1,551,170**
1997	**$ 4,553,055**
1998	**$ 3,578,784**
1999	**$ 5,367,120**
2000	**$ 7,171,589**
2001	**$ 6,884,592**
2002	**$ 10,026,374**
2003	**$ 9,852,480**
2004	**$ 14,660,568**
2005	**$ 17,567,269**
total	**$ 84,819,746**

LOW

Expenditure Projections for Repair of Studded Tire Damage

Assuming reconstruction when pavement reaches design life

Variable Surface Inputs

	AC	PCC
Design Life	12	25
Wear Rate	0.0226	0.0076

[redacted]

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	29,568	0	0	0	0	**29,568**
1996	77,088	0	0	0	0	**77,088**
1997	805,728	0	0	0	0	**805,728**
1998	34,848	147,312	0	0	0	**182,160**
1999	390,720	147,312	0	75,504	0	**613,536**
2000	1,309,968	312,048	0	538,560	0	**2,160,576**
2001	2,466,288	670,560	0	369,600	0	**3,506,448**
2002	1,334,784	524,832	0	7,392	0	**1,867,008**
2003	190,080	368,544	0	63,888	0	**622,512**
2004	1,769,856	365,904	0	455,136	0	**2,590,896**
2005	1,035,408	922,944	0	41,712	0	**2,000,064**
11-year	**9,444,336**	**3,459,456**	**0**	**1,551,792**	**0**	**$ 14,455,584**

Studded tire growth

1996-2005	2.50%
1986-1995	8.45%
1976-1985	0.00%
1968-1975	0.00%

[redacted]

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	1,647,233	0	0	0	0	**1,647,233**
1996	928,857	0	0	0	0	**928,857**
1997	0	0	0	0	0	**0**
1998	1,221,698	0	0	0	0	**1,221,698**
1999	2,949,005	0	0	0	0	**2,949,005**
2000	0	0	0	0	0	**0**
2001	0	0	0	0	0	**0**
2002	3,741,701	0	0	0	0	**3,741,701**
2003	0	0	0	0	0	**0**
2004	2,214,614	0	0	0	0	**2,214,614**
2005	1,659,054	0	0	0	0	**1,659,054**
11-year	**14,362,161**	**0**	**0**	**0**	**0**	**$ 14,362,161**

AC and PCC Total	
Projected Repair Totals	
1995	**$ 1,676,801**
1996	**$ 1,005,945**
1997	**$ 805,728**
1998	**$ 1,403,858**
1999	**$ 3,562,541**
2000	**$ 2,160,576**
2001	**$ 3,506,448**
2002	**$ 5,608,709**
2003	**$ 622,512**
2004	**$ 4,805,510**
2005	**$ 3,659,118**
total	**$ 28,817,745**

HIGH

Expenditure Projections for Repair of Studded Tire Damage

Assuming reconstruction when pavement reaches design life

Variable Surface Inputs

	AC	PCC
Design Life	16	35
Wear Rate	0.0545	0.011

Studded tire growth

1996-2005	2.50%
1986-1995	8.45%
1976-1985	0.00%
1968-1975	0.00%

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	1,284,096	1,899,216	0	1,555,488	0	**4,738,800**
1996	496,320	986,304	0	1,082,400	0	**2,565,024**
1997	2,521,728	1,921,392	0	1,826,352	21,120	**6,290,592**
1998	3,338,016	1,580,304	0	1,418,208	602,448	**6,938,976**
1999	5,132,160	877,008	0	1,437,216	10,560	**7,456,944**
2000	3,390,816	1,814,208	0	3,556,080	270,864	**9,031,968**
2001	7,116,384	2,465,232	0	6,660,192	79,728	**16,321,536**
2002	6,641,712	4,957,920	0	9,368,304	0	**20,967,936**
2003	7,359,792	5,512,320	0	9,097,968	764,016	**22,734,096**
2004	5,144,832	2,513,280	163,152	4,971,648	628,848	**13,421,760**
2005	8,342,400	4,114,704	0	5,898,288	1,751,904	**20,107,296**
11-year	**50,768,256**	**28,641,888**	**163,152**	**46,872,144**	**4,129,488**	**$ 130,574,928**

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	9,323,722	0	0	0	0	**9,323,722**
1996	2,949,005	0	0	0	0	**2,949,005**
1997	2,231,856	0	0	0	0	**2,231,856**
1998	7,123,034	6,453,952	0	0	0	**13,576,986**
1999	3,707,498	4,328,563	0	0	0	**8,036,061**
2000	2,124,093	0	0	0	0	**2,124,093**
2001	5,433,352	1,489,488	0	0	0	**6,922,840**
2002	1,617,264	998,976	0	0	0	**2,616,240**
2003	2,746,656	0	0	0	0	**2,746,656**
2004	2,921,424	1,489,488	0	0	0	**4,410,912**
2005	2,269,344	998,976	0	0	0	**3,268,320**
11-year	**42,447,249**	**15,759,443**	**0**	**0**	**0**	**$ 58,206,691**

AC and PCC Total

Projected Repair Totals

1995	**$ 14,062,522**
1996	**$ 5,514,029**
1997	**$ 8,522,448**
1998	**$ 20,515,962**
1999	**$ 15,493,005**
2000	**$ 11,156,061**
2001	**$ 23,244,376**
2002	**$ 23,584,176**
2003	**$ 25,480,752**
2004	**$ 17,832,672**
2005	**$ 23,375,616**
total	**$ 188,781,619**

Expenditure Projections for Repair of Studded Tire Damage

Assuming reconstruction when pavement reaches design life

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	1,043,856	280,368	0	237,600	0	**1,561,824**
1996	119,856	821,040	0	0	0	**940,896**
1997	605,088	1,083,456	0	350,064	0	**2,038,608**
1998	2,012,208	586,608	0	792,000	0	**3,390,816**
1999	3,352,272	1,207,008	0	281,424	0	**4,840,704**
2000	1,726,032	907,632	0	2,592,480	0	**5,226,144**
2001	3,625,776	1,081,344	0	856,416	613,008	**6,176,544**
2002	2,807,376	991,056	0	3,917,232	164,208	**7,879,872**
2003	5,382,960	1,729,200	0	3,334,848	186,384	**10,633,392**
2004	3,895,584	4,348,608	0	5,891,424	0	**14,135,616**
2005	6,238,320	4,469,520	0	4,913,040	364,848	**15,985,728**
11-year	**30,809,328**	**17,505,840**	**0**	**23,166,528**	**1,328,448**	**$ 72,810,144**

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	5,848,517	0	0	0	0	**5,848,517**
1996	3,289,891	0	0	0	0	**3,289,891**
1997	3,134,319	0	0	0	0	**3,134,319**
1998	2,286,768	0	0	0	0	**2,286,768**
1999	1,157,904	0	0	0	0	**1,157,904**
2000	7,367,705	6,039,855	0	0	0	**13,407,560**
2001	2,324,988	4,742,659	0	0	0	**7,067,647**
2002	4,274,870	0	0	0	0	**4,274,870**
2003	1,623,072	1,393,920	0	0	0	**3,016,992**
2004	1,941,984	95,568	0	0	0	**2,037,552**
2005	832,656	998,976	0	0	0	**1,831,632**
11-year	**34,082,673**	**13,270,979**	**0**	**0**	**0**	**$ 47,353,651**

Variable Surface Inputs

	AC	PCC
Design Life	16	35
Wear Rate	0.0386	0.0093

Studded tire growth

1996-2005	2.50%
1986-1995	8.45%
1976-1985	0.00%
1968-1975	0.00%

AC and PCC Total

Projected Repair Totals

1995	**$ 7,410,341**
1996	**$ 4,230,787**
1997	**$ 5,172,927**
1998	**$ 5,677,584**
1999	**$ 5,998,608**
2000	**$ 18,633,704**
2001	**$ 13,244,191**
2002	**$ 12,154,742**
2003	**$ 13,650,384**
2004	**$ 16,173,168**
2005	**$ 17,817,360**
total	**$ 120,163,795**

LOW

Expenditure Projections for Repair of Studded Tire Damage

Assuming reconstruction when pavement reaches design life

Variable Surface Inputs

	AC	PCC
Design Life	16	35
Wear Rate	0.0226	0.0076

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	29,568	0	0	0	0	**29,568**
1996	77,088	0	0	0	0	**77,088**
1997	805,728	2,640	0	0	0	**808,368**
1998	34,848	147,312	0	0	0	**182,160**
1999	508,992	147,312	0	75,504	0	**731,808**
2000	1,309,968	312,048	0	538,560	0	**2,160,576**
2001	2,645,808	670,560	0	369,600	0	**3,685,968**
2002	1,393,920	524,832	0	165,792	0	**2,084,544**
2003	733,920	594,000	0	63,888	0	**1,391,808**
2004	2,438,304	1,038,048	0	910,272	0	**4,386,624**
2005	1,008,480	821,568	0	1,175,856	10,560	**3,016,464**
11-year	**10,986,624**	**4,258,320**	**0**	**3,299,472**	**10,560**	**$ 18,554,976**

Studded tire growth

1996-2005	2.50%
1986-1995	8.45%
1976-1985	0.00%
1968-1975	0.00%

	Reg 1	Reg 2	Reg 3	Reg 4	Reg 5	Statewide
1995	1,647,233	0	0	0	0	**1,647,233**
1996	3,407,409	0	0	0	0	**3,407,409**
1997	0	0	0	0	0	**0**
1998	4,083,766	0	0	0	0	**4,083,766**
1999	3,329,165	0	0	0	0	**3,329,165**
2000	562,306	0	0	0	0	**562,306**
2001	281,952	0	0	0	0	**281,952**
2002	6,283,011	0	0	0	0	**6,283,011**
2003	1,917,878	6,453,952	0	0	0	**8,371,829**
2004	2,539,334	4,328,563	0	0	0	**6,867,897**
2005	1,060,752	0	0	0	0	**1,060,752**
11-year	**25,112,805**	**10,782,515**	**0**	**0**	**0**	**$ 35,895,320**

AC and PCC Total	
Projected Repair Totals	
1995	**$ 1,676,801**
1996	**$ 3,484,497**
1997	**$ 808,368**
1998	**$ 4,265,926**
1999	**$ 4,060,973**
2000	**$ 2,722,882**
2001	**$ 3,967,920**
2002	**$ 8,367,555**
2003	**$ 9,763,637**
2004	**$ 11,254,521**
2005	**$ 4,077,216**
total	**$ 54,450,296**

Appendix H: Estimates of Annual Expenditure Costs Adjusted for Lightweight Studs

High Wear Rate

Long Life		Optimistic factor	Pessimistic expenditure	Optimistic factor	Optimistic expenditure	Pessimistic factor	Pessimistic expenditure	Pessimistic factor	Optimistic expenditure
1995	14,062,522	1	$ 14,062,522	1	$ 14,062,522	1	$ 14,062,522	1	$ 14,062,522
1996	5,514,029	1	$ 5,514,029	1	$ 5,514,029	1	$ 5,514,029	1	$ 5,514,029
1997	8,522,448	0.9	$ 7,670,203	0.87	$ 7,414,530	0.95	$ 8,096,326	0.935	$ 7,968,489
1998	20,515,962	0.8	$ 16,412,769	0.74	$ 15,181,812	0.9	$ 18,464,365	0.87	$ 17,848,887
1999	15,493,005	0.7	$ 10,845,104	0.61	$ 9,450,733	0.85	$ 13,169,054	0.805	$ 12,471,869
2000	11,156,061	0.6	$ 6,693,637	0.48	$ 5,354,909	0.8	$ 8,924,849	0.74	$ 8,255,485
2001	23,244,376	0.6	$ 13,946,626	0.48	$ 11,157,301	0.75	$ 17,433,282	0.675	$ 15,689,954
2002	23,584,176	0.6	$ 14,150,506	0.48	$ 11,320,404	0.75	$ 17,688,132	0.675	$ 15,919,319
2003	25,480,752	0.6	$ 15,288,451	0.48	$ 12,230,761	0.75	$ 19,110,564	0.675	$ 17,199,508
2004	17,832,672	0.6	$ 10,699,603	0.48	$ 8,559,683	0.75	$ 13,374,504	0.675	$ 12,037,054
2005	23,375,616	0.6	$ 14,025,370	0.48	$ 11,220,296	0.75	$ 17,531,712	0.675	$ 15,778,541
	188,781,619		$ 129,308,819		$ 111,466,979		$ 153,369,340		$ 142,745,656
Base design life		**Optimistic factor**	**Pessimistic expenditure**	**Optimistic factor**	**Optimistic expenditure**	**Pessimistic factor**	**Pessimistic expenditure**	**Pessimistic factor**	**Optimistic expenditure**
1995	10,577,899	1	$ 10,577,899	1	$ 10,577,899	1	$ 10,577,899	1	$ 10,577,899
1996	5,051,501	1	$ 5,051,501	1	$ 5,051,501	1	$ 5,051,501	1	$ 5,051,501
1997	7,680,816	0.9	$ 6,912,734	0.87	$ 6,682,310	0.95	$ 7,296,775	0.935	$ 7,181,563
1998	18,473,968	0.8	$ 14,779,175	0.74	$ 13,670,736	0.9	$ 16,626,571	0.87	$ 16,072,352
1999	14,670,381	0.7	$ 10,269,267	0.61	$ 8,948,933	0.85	$ 12,469,824	0.805	$ 11,809,657
2000	10,963,341	0.6	$ 6,578,005	0.48	$ 5,262,404	0.8	$ 8,770,673	0.74	$ 8,112,873
2001	21,619,720	0.6	$ 12,971,832	0.48	$ 10,377,466	0.75	$ 16,214,790	0.675	$ 14,593,311
2002	22,893,024	0.6	$ 13,735,814	0.48	$ 10,988,652	0.75	$ 17,169,768	0.675	$ 15,452,791
2003	24,406,095	0.6	$ 14,643,657	0.48	$ 11,714,925	0.75	$ 18,304,571	0.675	$ 16,474,114
2004	14,512,608	0.6	$ 8,707,565	0.48	$ 6,966,052	0.75	$ 10,884,456	0.675	$ 9,796,010
2005	23,861,437	0.6	$ 14,316,862	0.48	$ 11,453,490	0.75	$ 17,896,078	0.675	$ 16,106,470
	174,710,791		$ 118,544,311		$ 101,694,367		$ 141,262,907		$ 131,228,542
Interm. Design Life		**Optimistic factor**	**Pessimistic expenditure**	**Optimistic factor**	**Optimistic expenditure**	**Pessimistic factor**	**Pessimistic expenditure**	**Pessimistic factor**	**Optimistic expenditure**
1995	5,473,118	1	$ 5,473,118	1	$ 5,473,118	1	$ 5,473,118	1	$ 5,473,118
1996	4,970,717	1	$ 4,970,717	1	$ 4,970,717	1	$ 4,970,717	1	$ 4,970,717
1997	5,474,304	0.9	$ 4,926,874	0.87	$ 4,762,644	0.95	$ 5,200,589	0.935	$ 5,118,474
1998	9,958,537	0.8	$ 7,966,829	0.74	$ 7,369,317	0.9	$ 8,962,683	0.87	$ 8,663,927
1999	8,805,866	0.7	$ 6,164,106	0.61	$ 5,371,578	0.85	$ 7,484,986	0.805	$ 7,088,722
2000	11,348,253	0.6	$ 6,808,952	0.48	$ 5,447,162	0.8	$ 9,078,603	0.74	$ 8,397,707
2001	17,835,544	0.6	$ 10,701,327	0.48	$ 8,561,061	0.75	$ 13,376,658	0.675	$ 12,038,992
2002	17,174,784	0.6	$ 10,304,870	0.48	$ 8,243,896	0.75	$ 12,881,088	0.675	$ 11,592,979
2003	20,193,480	0.6	$ 12,116,088	0.48	$ 9,692,871	0.75	$ 15,145,110	0.675	$ 13,630,599
2004	19,048,837	0.6	$ 11,429,302	0.48	$ 9,143,442	0.75	$ 14,286,628	0.675	$ 12,857,965
2005	23,163,993	0.6	$ 13,898,396	0.48	$ 11,118,716	0.75	$ 17,372,994	0.675	$ 15,635,695
	143,447,433		$ 94,760,579		$ 80,154,523		$ 114,233,174		$ 105,468,897

Low Wear Rate									
Long Life		Optimistic factor	Pessimistic expenditure	Optimisti factor	Optimistic expenditure	Pessimisti factor	Pessimistic expenditure	Pessimistic factor	Optimistic expenditure
1995	1,676,801	1	$ 1,676,801	1	$ 1,676,801	1	$ 1,676,801	1	$ 1,676,801
1996	3,484,497	1	$ 3,484,497	1	$ 3,484,497	1	$ 3,484,497	1	$ 3,484,497
1997	808,368	0.9	$ 727,531	0.87	$ 703,280	0.95	$ 767,950	0.935	$ 755,824
1998	4,265,926	0.8	$ 3,412,741	0.74	$ 3,156,785	0.9	$ 3,839,333	0.87	$ 3,711,355
1999	4,060,973	0.7	$ 2,842,681	0.61	$ 2,477,194	0.85	$ 3,451,827	0.805	$ 3,269,083
2000	2,722,882	0.6	$ 1,633,729	0.48	$ 1,306,983	0.8	$ 2,178,305	0.74	$ 2,014,932
2001	3,967,920	0.6	$ 2,380,752	0.48	$ 1,904,602	0.75	$ 2,975,940	0.675	$ 2,678,346
2002	8,367,555	0.6	$ 5,020,533	0.48	$ 4,016,426	0.75	$ 6,275,666	0.675	$ 5,648,100
2003	9,763,637	0.6	$ 5,858,182	0.48	$ 4,686,546	0.75	$ 7,322,728	0.675	$ 6,590,455
2004	11,254,521	0.6	$ 6,752,712	0.48	$ 5,402,170	0.75	$ 8,440,890	0.675	$ 7,596,801
2005	4,077,216	0.6	$ 2,446,330	0.48	$ 1,957,064	0.75	$ 3,057,912	0.675	$ 2,752,121
	54,450,296		$ 36,236,490		$ 30,772,348		$ 43,471,850		$ 40,178,317
Base Life		Optimistic factor	Pessimistic expenditure	Optimisti factor	Optimistic expenditure	Pessimisti factor	Pessimistic expenditure	Pessimistic factor	Optimistic expenditure
1995	1,676,801	1	$ 1,676,801	1	$ 1,676,801	1	$ 1,676,801	1	$ 1,676,801
1996	1,710,594	1	$ 1,710,594	1	$ 1,710,594	1	$ 1,710,594	1	$ 1,710,594
1997	805,728	0.9	$ 725,155	0.87	$ 700,983	0.95	$ 765,442	0.935	$ 753,356
1998	3,472,051	0.8	$ 2,777,641	0.74	$ 2,569,318	0.9	$ 3,124,846	0.87	$ 3,020,684
1999	3,942,701	0.7	$ 2,759,891	0.61	$ 2,405,048	0.85	$ 3,351,296	0.805	$ 3,173,874
2000	2,560,258	0.6	$ 1,536,155	0.48	$ 1,228,924	0.8	$ 2,048,206	0.74	$ 1,894,591
2001	3,890,832	0.6	$ 2,334,499	0.48	$ 1,867,599	0.75	$ 2,918,124	0.675	$ 2,626,312
2002	7,672,707	0.6	$ 4,603,624	0.48	$ 3,682,899	0.75	$ 5,754,530	0.675	$ 5,179,077
2003	1,326,336	0.6	$ 795,802	0.48	$ 636,641	0.75	$ 994,752	0.675	$ 895,277
2004	7,253,846	0.6	$ 4,352,307	0.48	$ 3,481,846	0.75	$ 5,440,384	0.675	$ 4,896,346
2005	3,483,294	0.6	$ 2,089,976	0.48	$ 1,671,981	0.75	$ 2,612,471	0.675	$ 2,351,224
	37,795,148		$ 25,362,446		$ 21,632,635		$ 30,397,446		$ 28,178,136
Interm. Life		Optimistic factor	Pessimistic expenditure	Optimisti factor	Optimistic expenditure	Pessimisti factor	Pessimistic expenditure	Pessimistic factor	Optimistic expenditure
1995	1,676,801	1	$ 1,676,801	1	$ 1,676,801	1	$ 1,676,801	1	$ 1,676,801
1996	1,005,945	1	$ 1,005,945	1	$ 1,005,945	1	$ 1,005,945	1	$ 1,005,945
1997	805,728	0.9	$ 725,155	0.87	$ 700,983	0.95	$ 765,442	0.935	$ 753,356
1998	1,403,858	0.8	$ 1,123,086	0.74	$ 1,038,855	0.9	$ 1,263,472	0.87	$ 1,221,356
1999	3,562,541	0.7	$ 2,493,779	0.61	$ 2,173,150	0.85	$ 3,028,160	0.805	$ 2,867,846
2000	2,160,576	0.6	$ 1,296,346	0.48	$ 1,037,076	0.8	$ 1,728,461	0.74	$ 1,598,826
2001	3,506,448	0.6	$ 2,103,869	0.48	$ 1,683,095	0.75	$ 2,629,836	0.675	$ 2,366,852
2002	5,608,709	0.6	$ 3,365,225	0.48	$ 2,692,180	0.75	$ 4,206,531	0.675	$ 3,785,878
2003	622,512	0.6	$ 373,507	0.48	$ 298,806	0.75	$ 466,884	0.675	$ 420,196
2004	4,805,510	0.6	$ 2,883,306	0.48	$ 2,306,645	0.75	$ 3,604,132	0.675	$ 3,243,719
2005	3,659,118	0.6	$ 2,195,471	0.48	$ 1,756,377	0.75	$ 2,744,339	0.675	$ 2,469,905
	28,817,745		$ 19,242,490		$ 16,369,913		$ 23,120,003		$ 21,410,680