# Estimated Impacts of Deteriorating Highway Conditions to Oregon's Economy

## Modeling and Analysis Technical Report

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# Estimated Impact of Deteriorating Highway Conditions to Oregon's Economy

## Introduction

Oregon is falling behind on the fundamental need to preserve and maintain highways and bridges. The current budget forecast for the state highway system will not sustain the system condition and performance experienced today. Returns on new construction will not be fully realized as the aging system around it declines in performance. Insufficient preservation investment will create a growing need for maintenance expenditures. Maintenance expenditures will rise at an increasing rate as the highway system degrades, ultimately resulting in escalating deterioration in system conditions given current funding forecasts. Deteriorating highway conditions lead to higher transportation costs and other economic impacts.

## Background

The Oregon Department of Transportation (ODOT) is dedicated to providing a safe, efficient transportation system that supports economic opportunity and livable communities for Oregonians. In order to do this it is necessary to anticipate and plan for the future needs of Oregon. Long range planning for the highway system must account for a broad set of needs that vary by industry and commodity in order to support a competitive economy.

**Freight-Dependent Industries in Oregon**

- **High-value products**: computer and electronics manufacturing; wholesale trade; footwear; apparel and recreation products
- **General manufacturing:** metals; machinery; food and transportation equipment
- **Natural resource-dependent industries**: agriculture; forestry; fishing; wood and paper manufacturing

Implications of an aging highway system are not new to Oregon. In 2001, Ford's Bridge on I-5 was closed for emergency repairs. Traffic detoured through small towns created public safety concerns and stressed roads designed for lighter traffic, not heavy trucks using the interstate system. Truck freight was required to travel many miles out of direction, increasing shipping costs to Oregon businesses. At the time, ODOT predicted within 10 years 30 percent of state bridges would be posted with reduced weight limits.

With the passage of the third Oregon Transportation Investment Act (OTIA III) in 2003, ODOT was tasked with delivering a $1.3 billion program to repair or replace hundreds of aging highway bridges statewide. ODOT used innovative methods and processes to deliver the OTIA III State Bridge Delivery Program, such as design-build contracting, programmatic environmental permitting, and grouping or bundling nearby projects so local firms across the state could compete for contracts. ODOT's philosophy for the bridge program was based on stewardship: take care of what you have so current and future generations can prosper. The improved network of bridges spurred job growth during design and construction and helped preserve the

highway infrastructure fundamental to Oregon's economy.

Over the course of the OTIA III and the 2009 Oregon Jobs and Transportation Act (JTA), Oregon's transportation infrastructure continued to age and the need for sustaining system investment continues to rise. Even though the total number of miles driven on highways increases, Oregon's highway fund revenues are flat as vehicles become more fuel efficient and alternative fuels enter the market. At the same time, a significant portion of the ODOT budget goes towards paying off debt for the OTIA and JTA programs. ODOT has implemented business practices incorporating efficiencies and prioritizing investments in order to maximize the return on investment dollars. Meanwhile, the increasing risk associated with a major seismic event[1] provides a greater impetus for sustainable and continued preservation and maintenance of the Oregon highway system to support a competitive economy.

## Methodology

The purpose of this analysis is to evaluate high level economic implications associated with the current forecast agency budget compared to an alternative budget designed to preserve current conditions of state highways, roads and bridges.

For the purpose of this analysis, we assume the following:

- Purchasing power of the ODOT budget is treated as constant over time. Ignoring impacts of inflation for a high-level analysis such as this is methodologically reasonable. However, this is not likely to prevail in the real world. The cost of building roads has more than doubled since 1993 while highway-use revenue has not kept pace. If this trend continues, ODOT will fall even further behind the scenario presented here.
- Congestion levels will be impacted, but the impacts are not quantified for this analysis. Given the current budget forecast, capacity enhancement expenditures will be shifted to maintenance, which is expected to have measurable economic impacts.[2]
- The forecast model network includes local highways and roads; however, this analysis did not account for the additional stress imposed on local jurisdiction infrastructure to accommodate detours around state system restrictions; this is a major simplifying assumption given local infrastructure condition is declining and not built to withstand the higher level of use as the state system. Rerouting traffic off the state system onto local highways will negatively impact local system conditions and user costs, generating additional negative economic impacts not accounted for in this analysis.

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[1] ODOT Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification, May 2012 - http://www.oregon.gov/ODOT/TD/TP/Reports/Seismic%20Lifelines%20Evaluation%20Vulnerability%20Synthese%20and%20Identification.pdf; Oregon Highways Seismic Bridge Options Report, March 2013 - http://www.oregon.gov/ODOT/HWY/BRIDGE/docs/Oregon_Highways_Seismic_Options_Report_3_2013.pdf; The Oregon Resilience Plan - http://www.oregon.gov/OMD/OEM/osspac/docs/Oregon_Resilience_Plan_Final.pdf

[2] "The Cost of Highway Limitations and Traffic Delay to Oregon's Economy," Economic Development Research Group, prepared for the Oregon Business Council and Portland Business Alliance, 2007; http://www.portofportland.com/pdfpop/trade_trans_studies_costhwy_lmtns.pdf An update of this report in currently in progress and completion expected by the end of 2014.

- Safety will be impacted by declining highway conditions, but the economic impacts are not quantified for this analysis.
- Culverts are a major asset on the state system with declining condition and increasing risk of failures, but are not fully addressed for this high level strategic analysis.
- Highway user costs will rise as pavement condition deteriorates. The impacts of higher user costs are not directly accounted for in the modeling scenarios. An example of the potential increase in vehicle operating costs is provided in this report for a medium sedan to illustrate user impacts, but the total user costs associated with rougher pavement were not quantified for this analysis.

## Scenario Analysis

Two funding scenarios were developed for this analysis. The *Current Revenue / Deterioration Scenario* represents the current 20-year ODOT budget forecast for state highway spending. The *Maintain Current Conditions Scenario* represents a 20-year forecast for highway spending designed the preserve current highway conditions.

### Current Revenue / Deterioration Scenario

Under the current ODOT forecast funding, system preservation and maintenance cannot be sustained. The aging system will deteriorate at an increasing rate over time. The point at which users begin to see significant impacts to their vehicle operating costs is unlikely to appear for at least ten years. However, by the time operating costs are impacted, the cost of highway repairs escalates as the damage requires more extensive and expensive repairs. As preservation activity falls behind, the need for maintenance activity rises every year. In order to accommodate rising need, funding designated for modernization (new construction) is diverted into the maintenance budget. Under the current funding forecast, many bridges will become weight restricted as they deteriorate and become structurally deficient, forcing detours of heavy trucks.

### Maintain Current Conditions Scenario

The funding forecast for this scenario does not fully represent projected need, but is sufficient for ODOT to keep the state highway system close to conditions the traveling public experiences today. A key aspect of this scenario is avoiding a rise in state bridge weight restrictions, which creates negative impacts on the Oregon economy statewide and regionally.

#### *Budgets*

The two scenario budgets are presented in Table 1 for years 2016, 2020, 2025, 2030 and 2035. The *Current Revenue / Deterioration Scenario* budget sustains a constant level of spending for Preservation, Bridge and Other throughout the 20-year period.[3] The Maintenance budget is increased by 3% each year as the Modernization budget is reduced accordingly and shifted to Maintenance until 2025 when the Modernization budget is zero and all budgets remain constant through 2035.

[3] Definitions used in this document for budget categories are consistent with the ODOT Highway Division budget category descriptions.

The *Maintain Current Conditions Scenario* budget assumes Maintenance is 20% higher than today's spending and remains constant over time to sustain a maintenance budget over the full 20-year period. The Preservation budget is double the *Current Revenue / Deterioration Scenario* amount and remains fixed over the 20-year period. The Bridge budget is more than four times larger than the *Current Revenue / Deterioration Scenario* and remains constant over the 20-year period. The Modernization budget starts out double the amount in the *Current Revenue / Deterioration Scenario* and remains fixed over time. The Other spending category, which includes safety and operations, local government and special operations, remains the same as the *Current Revenue / Deterioration Scenario*. The total annual budget is about 77% higher in this scenario.

**Table 1 Current Revenue / Deterioration Scenario (Scenario 1) and Maintain Current Conditions Scenario (Scenario 2) Budgets by Spending Category for Select Years (millions of 2014 dollars)**

| | 2016 | | 2020 | | 2025 | | 2030 | | 2035 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Scenario 1 | Scenario 2 | Scenario 1 | Scenario 2 | Scenario 1 | Scenario 2 | Scenario 1 | Scenario 2 | Scenario 1 | Scenario 2 |
| Maintenance | 250 | 300 | 281 | 300 | 325 | 300 | 325 | 300 | 325 | 300 |
| Pavement | 100 | 200 | 100 | 200 | 100 | 200 | 100 | 200 | 100 | 200 |
| Bridge | 50 | 230 | 50 | 230 | 50 | 230 | 50 | 230 | 50 | 230 |
| Mod | 75 | 150 | 44 | 150 | 0 | 150 | 0 | 150 | 0 | 150 |
| Other* | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Total | 525 | 930 | 525 | 930 | 525 | 930 | 525 | 930 | 525 | 930 |
| *Other category of expenditures includes Safety and Operations, Local Government and Special Operations | | | | | | | | | | |

## Analysis Tool: Statewide Integrated Model

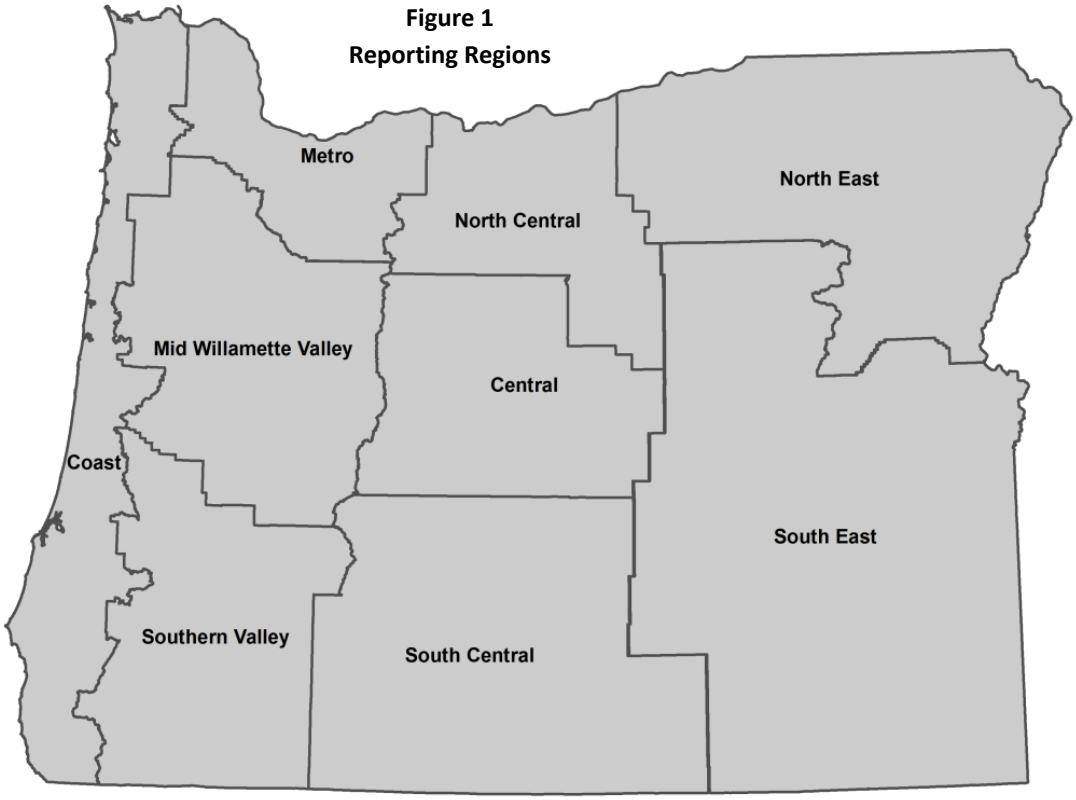
The second generation Oregon Statewide Integrated Model (SWIM2) is used for the scenario analysis. SWIM2 is a data driven forecast model designed to represent the Oregon economy with respect to land-use and transportation by simulating the activity and market exchanges made by people and businesses. Household and business location decisions are simulated, as well as the travel generated by activities - such as commuting to work, purchasing commodities for industrial production and transporting final goods to markets within Oregon and outside of the state. SWIM2 is designed for statewide and regional long range transportation planning and policy analysis. Information from the SWIM2 is designed to inform other modeling tools, such as metropolitan planning organization travel models, freight models, and regional studies. The design of SWIM2 has been guided and vetted by an internationally recognized peer review panel of experts. More information on the history, development and characteristics of the SWIM2 is provided in Appendix A.

# Findings

Scenario budgets were used to forecast reasonably likely timing for bridge weight restrictions, which impact the flow of freight trucks. Thus, for this analysis bridge conditions generate significant impacts on transportation costs. Figure 1 illustrates the reporting regions used throughout this analysis.

Bridge restrictions are based on an engineering analysis of the original bridge design, taking into account current bridge condition. When the analysis shows that the load effects of a truck exceed the ability of the bridge to carry that load, it triggers a need to restrict the bridge. Figure 2 illustrates the number of bridges forecast to be

**Figure 1**
**Reporting Regions**

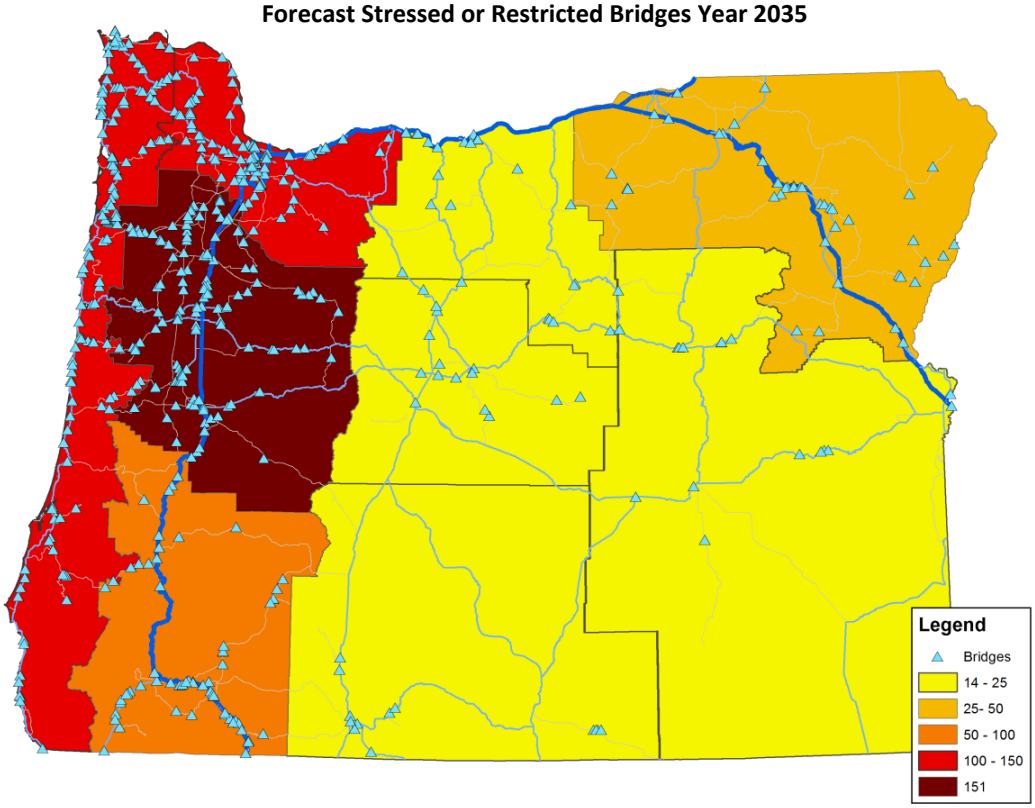



stressed and restricted in the *Current Revenue / Deterioration Scenario*.

The number of stressed bridges varies by region. There are fewer bridge restrictions east of the Cascades, but also fewer highways offering alternative routes. The Mid-Willamette Valley region had the largest number of bridge restrictions. There are alternative routes available in the denser urban areas, but not for the western portion of the region. This is similarly the case for the Metro area. Southern Valley restrictions are concentrated on the southern I-5 corridor and two routes between I-5 and the coast, as well as US 199 to the California border. The Oregon Coast region has restrictions along the entire US 101 corridor as well as most of the highways providing access to I-5. The restrictions illustrated on the interstate highways represent locations adjacent to I-5 and I-84, not on the interstate highways directly.

Figure 2 represents ODOT's 20 year forecast of stressed bridges/potential bridge restrictions for the regions identified in Figure 1. It is important to note Oregon's inventory of aging bridges suggests significantly more restrictions will occur beyond 20 years. The 20 year forecast used for this analysis misses the impacts to the highway system from bridges restricted in the late years of the scenarios and the additional bridge restrictions expected beyond year 2035.

**Figure 2**
**Forecast Stressed or Restricted Bridges Year 2035**

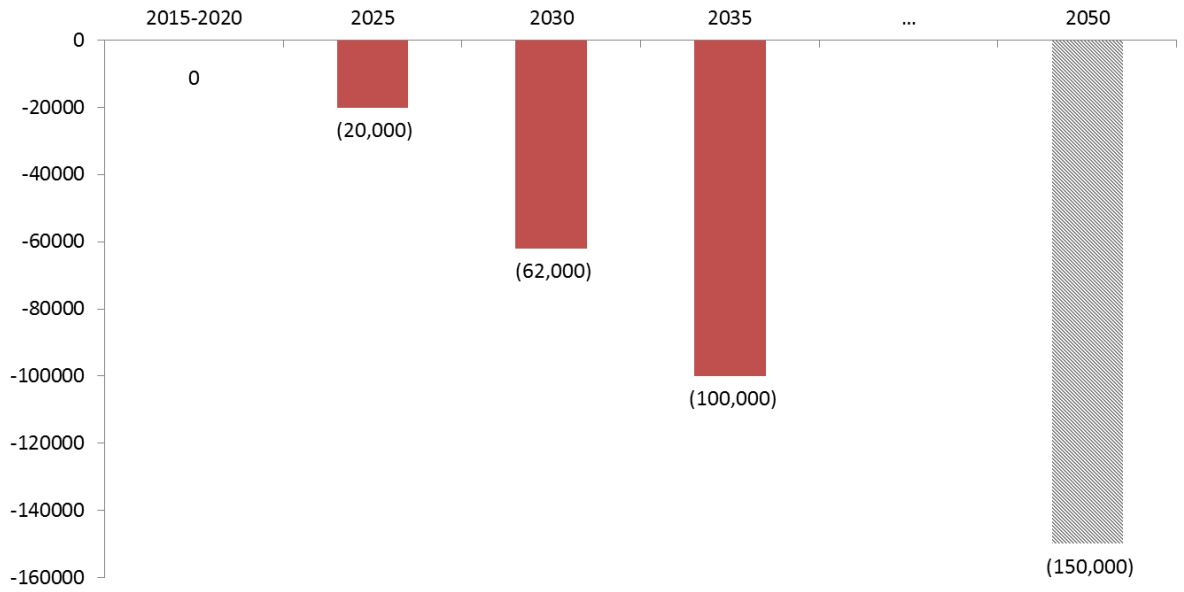



## Economic Impacts from the Current Revenues / Deterioration Scenario

Declining pavement and bridge conditions impact the Oregon economy. Poor conditions translate into higher transportation costs to businesses and households. Higher costs reduce connectivity and accessibility of businesses to goods and labor markets, workers to jobs and affordable housing. Weight restricted bridges force heavy trucks to use detours or separate loads into lighter trucks, when possible. Depending on the number of bridges restricted and alternative routes available, the impact on accessibility varies by region and industry. Industries relying on heavy goods are most affected.

The Oregon economy is forecast to grow in both scenarios. Figure 3 illustrates the estimated number of jobs forfeited due to higher transportation costs imposed in Oregon by declining highway and bridge conditions. Impacts to transportation costs start out small but increase rapidly; within 20 years there is significant impact on Oregon job growth. The *Current Revenue / Deterioration Scenario*, which reflects current funding levels, forecasts a 27 percent increase in the number of jobs between 2020 and 2035. The *Maintain Current Conditions Scenario*, which reflects funding levels designed to preserve current highway conditions, forecasts a 32 percent increase in jobs over the same time period. The number of estimated jobs lost increases over time. Between year 2025 and 2030 the number triples. By 2035 the number rises another 65 percent. The magnitude of these changes and other analytical results prompted further exploration of the impacts beyond year 2035. The two scenarios were extended out to year 2050 in a simplified manner by holding the 2035 highway and bridge conditions constant and allowing the scenarios to run 15 additional years to reveal the economic impacts of 2035 conditions. By year 2050, the number of forfeited jobs forecast is 150,000, representing 45 percent more jobs lost within an additional 15 years.

**Figure 3**
**Estimated Jobs Forfeited Due to Rising Transportation Costs Associated with Declining Highway and Bridge Conditions**




Looking back at job losses from recent recessions helps put the magnitude of these figures into perspective. From the peak number of jobs in the first quarter of 2007 to the low in the third quarter of 2009 Oregon realized a seasonally adjusted loss of more than 220,000 private-sector jobs.[4] This was one of the most severe recessions to hit Oregon. Total job losses during the 2001 recession (measured between the first quarter of 2001 and second quarter of 2003) numbered about 62,000. In other words, Oregon would face permanent job losses equivalent to the 2001 recession due to deteriorating highway and bridge conditions.

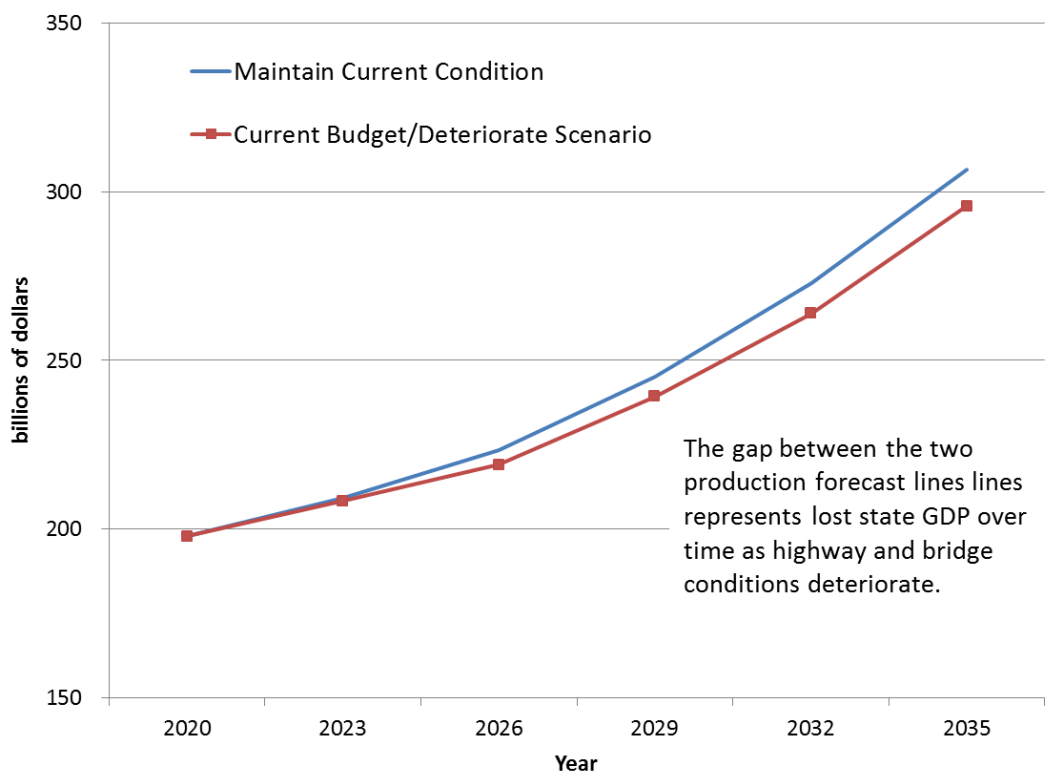
A similar pattern is forecast for state production levels. Table 2 reports forecast change in statewide industry production. Oregon industry production activity is forecast to increase about 49 percent between year 2020 and 2035 under the current 20-year budget and about 55 percent if highway and bridge conditions are preserved. 2013 Oregon Gross Domestic Product (GDP) reported by the Bureau of Economic Analysis was $219.6 billion, which occurred given current highway conditions. In the event GDP rises 55 percent instead of 49 percent by year 2035, the difference in cumulative year over year[5] GDP is about $94 billion in additional state production (in current dollars) associated with preserved highway conditions. By year 2050, this amount is estimated to be $334 billion, $240 billion more GDP generated over an additional 15 years.

[4] Peniston, Barbara, "Unbalanced Growth in Oregon: Two and a Half Years After the Great Recession," Oregon Employment Department, March 2013 http://www.qualityinfo.org/olmisj/ArticleReader?itemid=00008551
[5] Cumulative year over year is a standard measure of total impacts used in finance.

| Table 2. Forecast Change in State Production by Scenario | | | |
|---|---|---|---|
| Range of Years | Current Revenue / Deterioration Scenario | Maintain Current Conditions Scenario | Simple Difference |
| 2020 to 2035 | +49 % | +55 % | 6 % |
| 2020 to 2050 | +174 % | +183 % | 9 % |

Figure 4 presents forecast state production for both scenarios side-by-side. The gap between the two forecast lines illustrates lost state GDP over time as highway conditions deteriorate. Avoiding such losses represents value added by maintaining current highway conditions and supporting Oregon's economic competitiveness.

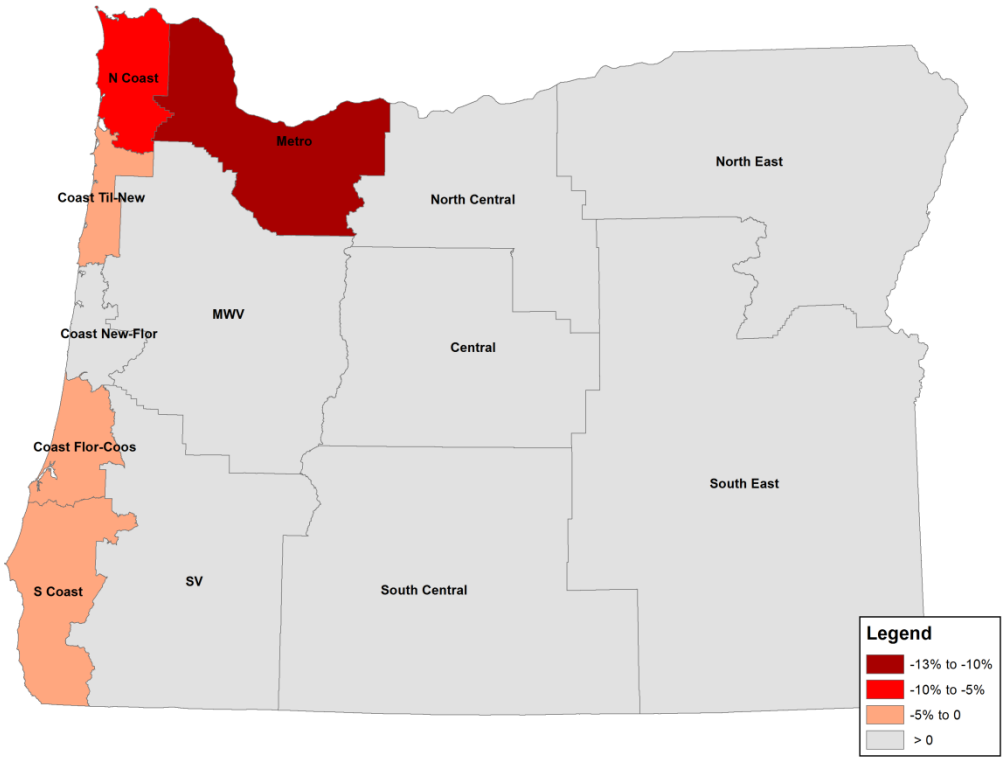
**Figure 4. State Production by Scenario** (2014 dollars)




Economic impacts differ by region of the state. Figure 5 illustrates the difference between the two scenarios' forecast change in production by region. Regions east of the Oregon Cascades are not negatively impacted in the *Current Revenue / Deterioration Scenario*. This is also the case for the Southern Valley region. For Mid-Willamette Valley and the Central Oregon Coast between Newport and Florence production levels are mostly the same in both scenarios. Most of the Oregon Coast has lower production levels in the *Current Revenue / Deterioration Scenario* than the *Maintain Current Conditions Scenario*, since there are fewer route alternatives as conditions decline. The difference in production growth is greatest for the North Coast where heavy goods production occurs. By far the largest impact on regional production occurs in the Portland Metro area. Regional

production is more than 10 percent lower in the *Current Revenue / Deterioration Scenario* than the *Maintain Current Conditions Scenario*. Portland is the gateway to Oregon markets and a major internal consumption center. Production across the state becomes more localized, internal trade within Oregon shrinks as well as export trade outside the state as the price of our goods rise due to higher transportation costs and we become less competitive with other states.

**Figure 5. Difference Between Current Revenues/Deterioration Scenario and Maintain Current Conditions Scenario Forecast Change in Regional Production 2020 to 2035**




## Vehicle Operating Costs

A recent report by the Transportation Research Board's National Cooperative Highway Research Program (NCHRP Report 720) "Estimating the Effects of Pavement Conditions on Vehicle Operating Costs" developed detailed estimates of the effects of pavement condition on vehicle operating costs, repair and maintenance costs[6]. The NCHRP report points out:

[6] NCHRP Report 720 "Estimating the Effects of Pavement Condition on Vehicle Operating Costs." 2012, Transportation Research Board, Table 7-3 and Table 7-5, 55 mph speed.

*"While the infrastructure costs borne by road agencies are substantial, the costs borne by the road users are even greater. Therefore, vehicle operating costs should be considered by highway agencies when evaluating pavement investment strategies."*

The report estimated the percentage change in costs for a range of pavement conditions.[7] Using NCHRP estimates in combination with Bankrate.com car ownership costs, potential impacts of pavement condition on Oregon highway user costs can be calculated. The NCHRP tables used for these calculations are provided in Appendix A. Table 3 below provides an example of the impact of very rough pavement condition on the fuel efficiency, tire wear and repair and maintenance costs for a medium sedan.[8] Overall, very rough pavement has the potential to increase overall vehicle auto operating costs by 22 percent for a medium sedan. Table 4 presents impacts in terms of potential additional dollars spent due to operating on very rough pavement. Higher repair and fuel costs have the potential to rise nearly 30 percent when driving on rough pavement. Transportation costs are a significant budget item for households, so increasing costs in this sector will impact household economic activity.

**Table 3: Impact of Rough Pavement on Vehicle Operating Costs: Example Medium Sedan**

| **NCHRP Report 720** | **Estimated Percent Change Due to Very Rough Pavement*** |
|---|---|
| **Fuel Efficiency** | Drops 12% |
| **Tire Wear** | Increases 5% |
| **Repair and Maintenance** | Increases 70% |
| **Total Net Effect on Auto Operating Costs** | Increase of 28% |

*International Roughness Index = 6

**Table 4. Estimated Range in Cost of Repairs and Fuel Associated with Pavement Condition, 2013 dollars, medium sedan**

| **Bankrate.com Estimated Costs** | **Cost Driving on Smooth Pavement** | **Cost Driving on Very Rough Pavement** |
|---|---|---|
| Oregon Repairs | $380 | $646 |
| Oregon Gasoline | $942 | $1,055 |
| **Total** | **$1,322** | **$1,701** |

As highway system conditions decline over time, costs associated with fixed ownership costs, such as insurance and depreciation, may increase as well. These additional user costs are not captured in the forecast model used

[7] Pavement conditions are measured using the International Roughness Index (IRI)

[8] The NCHRP report used a 2008 Mitsubishi Galant to represent a medium car. The International Roughness Index (IRI) is used to measure pavement surface roughness.

for this analysis. Thus, none of the impacts of rising highway user costs related to pavement condition are accounted for within the estimated impacts to jobs, workers and state production.

## Pavement Conditions

The goal of the ODOT pavement preservation program is to keep state highways in the best condition possible, for the lowest cost within a limited budget, by taking a life-cycle cost approach to preservation and maintenance. The most cost-effective strategy is applying preservation treatments on highways while they are still in "fair or better" condition, which extends pavement life at a reduced resurfacing cost. If not properly maintained, roads will deteriorate to very poor condition and require complete reconstruction to fix them. Figure 6 illustrates the importance of performing the "right treatment to the right road at the right time." Figure 7 provides illustrated examples of pavement condition.

Figure 6 Pavement Treatments Through Out Pavement Lifecycle

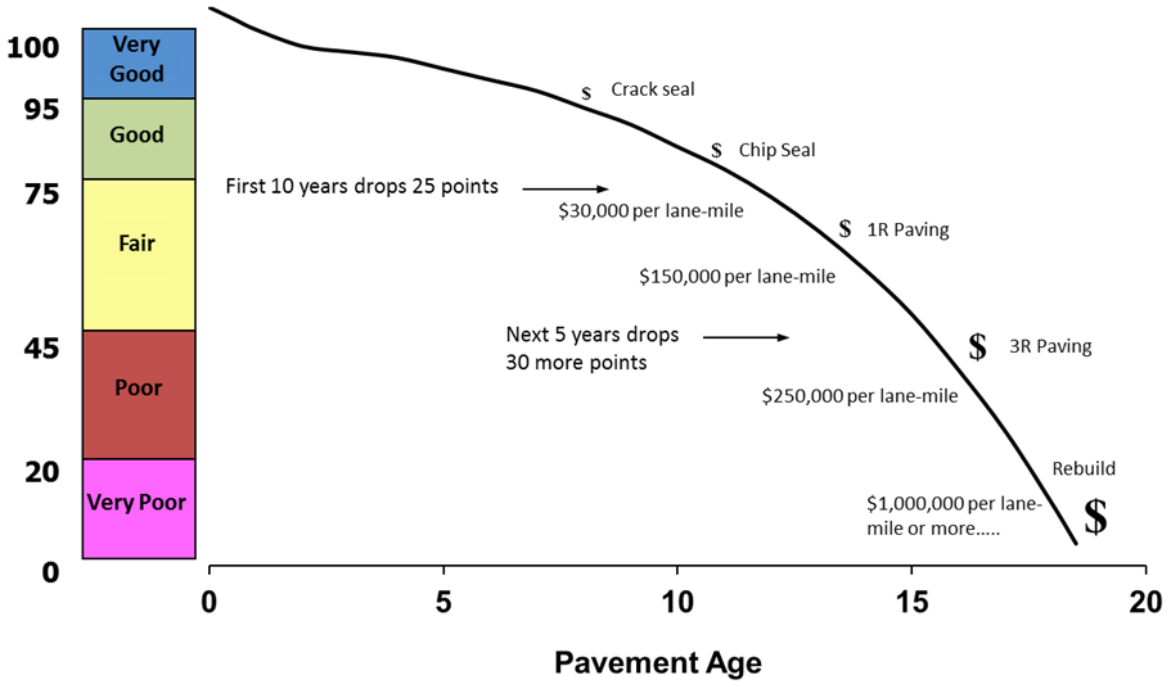


**Figure 7 Illustration of Pavement Condition**

**Very Good**

**Very Poor**

In the later stages of a pavement's service life, deterioration occurs at an increasing rate making it critically important not to defer preservation treatment too long. If a preservation treatment can be applied before a pavement reaches poor condition, the service life can be extended for a fraction of the cost of reconstruction. Deferring maintenance just a few years will cost much more in the long run. According to the American Association of State Highway and Transportation Officials (AASHTO), every dollar spent on road maintenance avoids $6 to $14 needed later to rebuild a road that has irreparably deteriorated[9].

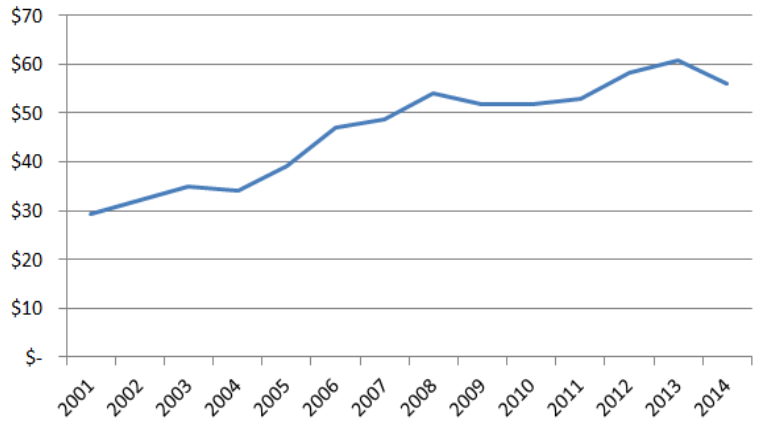
An estimated $200 million per year in current dollars for the next 20 years is sufficient to repair the backlog of high cost poor and very poor highways, while keeping the remaining state highways in "fair or better" condition. This funding level supports major repairs needed on routes with the worst pavement conditions, while providing for timely preventive preservation and maintenance on roads in fair to good condition.

Current funding forecast for the next 20 years estimate ODOT will have $100 million per year to invest in pavement preservation and repair work. This is about 30 percent less than pavement funding occurring over the last decade and about one-half of the actual need for pavement preservation and major repairs. Declining purchasing power (construction costs inflation) makes the business case even worse. Because construction costs rise over time, today's pavement budget paves little more than half what could be paved 10 years ago. Figure 8 illustrates the rise in asphalt costs since 2001[10].

[9] National Center for Pavement Preservation, Preservation Awareness Toolkit, Media Fact Sheet: https://www.tsp2.org/files/2012/01/News-release-template-4.pdf

[10] ODOT Office of Project Letting, nominal values not adjusted for inflation

**Figure 8 Total Asphalt Costs, Years 2001 – 2014 ($/ton)**




Because overall pavement preservation needs exceed available funding, the pavement preservation program follows a strategy developed, implemented, and refined over many years by ODOT's Pavement Committee leadership team. The strategy prioritizes pavement conditions by state highway classification into three layers. Interstate highways such as I-5 and I-84 are the highest priority and have the highest level of condition. State level routes like US-97, US-101, or US-26 are the next highest priority. Region and district level routes like OR-99E or OR-99W are at a lower priority. While this strategy allows the program to meet the resurfacing needs on the highest priority routes, the lower priority routes must wait even longer for resurfacing. In fact, on most of the lower traffic roads in the system, resurfacing projects are no longer programmed and treatments are limited only to seals and patching, leaving pavement to deteriorate over time.

Pavement preservation projects are also prioritized by cost effectiveness. Over the long run, it is more cost effective to do low cost thin resurfacing and seal treatments on pavements with only minor deterioration than to employ a "worst first" approach. In order to maximize investments, projects which can benefit from a long service life extension at low cost receive the highest priority. The project selection process does allow some flexibility to do higher cost projects or projects on lower priority routes, but the program provides a resurfacing mileage goal to assure that an appropriate mix of low cost and high cost projects are selected.

While the prioritization process follows a sound, logical and proven strategy, the net effect of the strategy and limited funding for pavement repair has resulted in declining pavement conditions on routes of local significance, particularly those district level state highways that act more like city streets than major thoroughfares. There are many routes in the Portland metro area in this category, such as Lombard Street or 82$^{nd}$ Avenue, illustrated in Figure 9 below, and pavement conditions on these routes have declined significantly over the years.

**Figure 9**

**Lombard Street (Northeast Portland Highway)** **82nd Avenue (Cascade Highway North)**

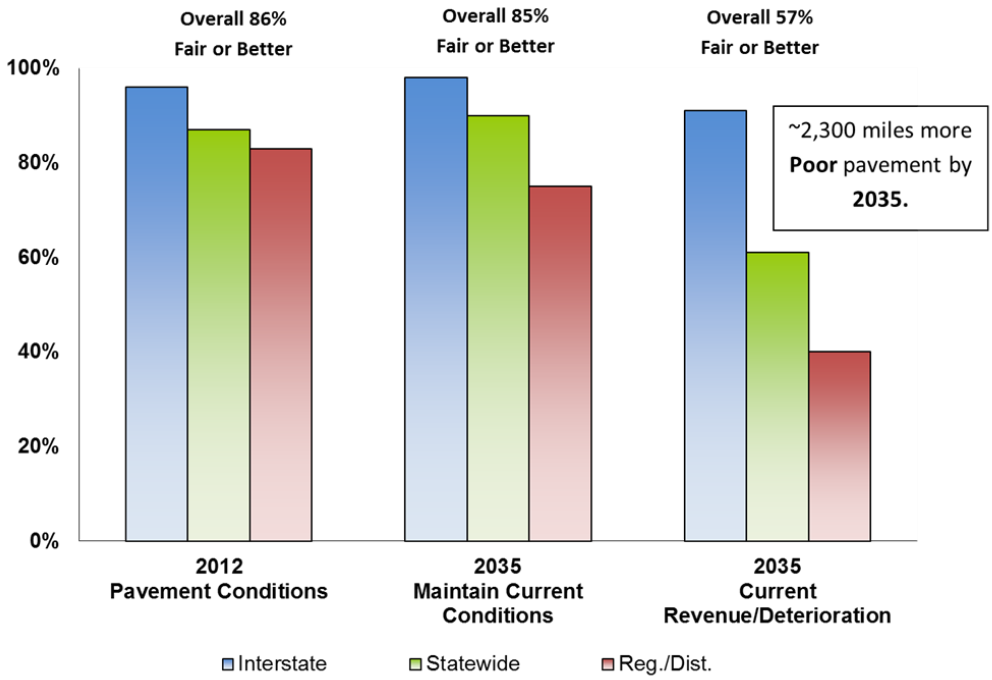
Urban routes often have many other features that may need to be addressed at the time of paving, such as utility conflicts, storm water quality requirements, ADA requirements, access management, community enhancements, traffic management, public affairs, and more. These issues make urban projects more complex and more expensive to deliver than rural projects.

At higher speeds, pavement in poor condition can make driving conditions hazardous due to potential for hydroplaning and vehicle damage from potholed surfaces. Urban district level state highways are typically lower speed facilities where this risk is not as great. While everyone enjoys driving on smooth roads, rough surfaces become a safety issue on higher speed facilities. This is also a factor considered in determining project selection priorities, and tends to favor rural segments over urban ones.

After 20 years of funding at current forecast levels represented in the *Current Revenue / Deterioration Scenario*, pavement conditions will decline across the system. The greatest declines will be on the lower volume roads. By 2035, the estimated pavement condition by functional class for the *Maintain Current Conditions Scenario* and the *Current Revenue / Deterioration Scenario* is shown in Figure 10.

Because the Interstate System is a critical transportation system that carries far more traffic and freight than other routes, preservation investments will support interstates. By 2035, many segments will have reached the end of their structural life and these segments will need major rehabilitation or reconstruction to carry projected traffic. The condition on the statewide system of primary routes and the region and district level routes will decline dramatically. Routes east of US-97 will mostly receive just patching and chip seals and virtually no paving projects. This strategy will work for the next few years, but not for the long term. Also, a chip seal strategy is not a viable option for most primary routes west of the Cascades so crack sealing and patching become the only viable alternative to paving. State highways in local communities that require higher cost projects will likely receive only patching.

**Figure 10 Pavement Condition - Current and 2035 Forecast by Analysis Scenario**




Declining pavement conditions will shift the burden to ODOT maintenance crews to keep poor highways in a safe condition for travel. Maintenance budget demands for reactive maintenance activities, such as pothole patching and rut filling, will increase. It is estimated that the maintenance budget will need to increase so much that the budget for highway capacity expansion will eventually be totally consumed by increased pavement and bridge maintenance needs. Under current funding projections it is estimated to take 10 years for the maintenance budget to bring the highway capacity expansion budget to zero. Even with the assumed extra $75 million dollars per year assumed to be available for highway capacity expansion going to maintenance needs, there will still be substantial consequences to underfunding pavement preservation.

Despite extra spending towards maintenance, after 20 years of funding at current levels, there will be substantially more miles of poor and very poor roads than there are today. Figure 11 illustrates examples where pavement deterioration has reached an advanced state requiring complete reconstruction or major rehabilitation. It is estimated the number of roads in this condition will double or triple today's levels at current funding levels.

**Figure 11: Examples of Advanced Pavement Deterioration**

Over time, as road conditions deteriorate, thicker paving and/or complete replacement will become necessary at a higher cost. If significant deterioration occurs, pavement surface becomes rougher, vehicle operating costs rise and safety impacts occur. Beyond the 20 year horizon, poor pavement condition on some lower functional class roads will require reductions in posted speed to maintain safe travel and reduce chances of vehicle damage. Many of the lower functional class roads will be in poor condition and further deteriorate to very poor if maintenance funding is unavailable.

Assuming state highways will be maintained as paved facilities, after 20 years of operating at currently forecast funding levels, it is estimated that the state would need to spend between $3.4 billion to $5.2 billion in current dollars to return degraded pavement to conditions similar to levels seen on Oregon's highways today. For an additional $100 million per year, which totals to an extra $2 billion over that next 20 years, the state could preserve pavement condition at current levels and avoid the expensive option of waiting until replacement is necessary and the cost 70 percent to 160 percent higher. This approach would also avoid higher user costs for autos, commercial vehicles and trucks.

*Supplemental analysis revealed potential impacts of focusing efforts to maintain the interstate and high-volume state highways, while allowing low volume district highway pavement condition to deteriorate. Results indicate up to 50,000 jobs could be lost statewide, with the losses occurring in the Portland Metro region, Mid-Willamette Valley, South Central and North Eastern Oregon. The Alternative Scenario indicated impacts from bridge weight restrictions would affect the Oregon Coast and the Portland Metro area the most, but an inability to maintain low volume district highways further extends the impacts across the state. See Appendix C for more details.*

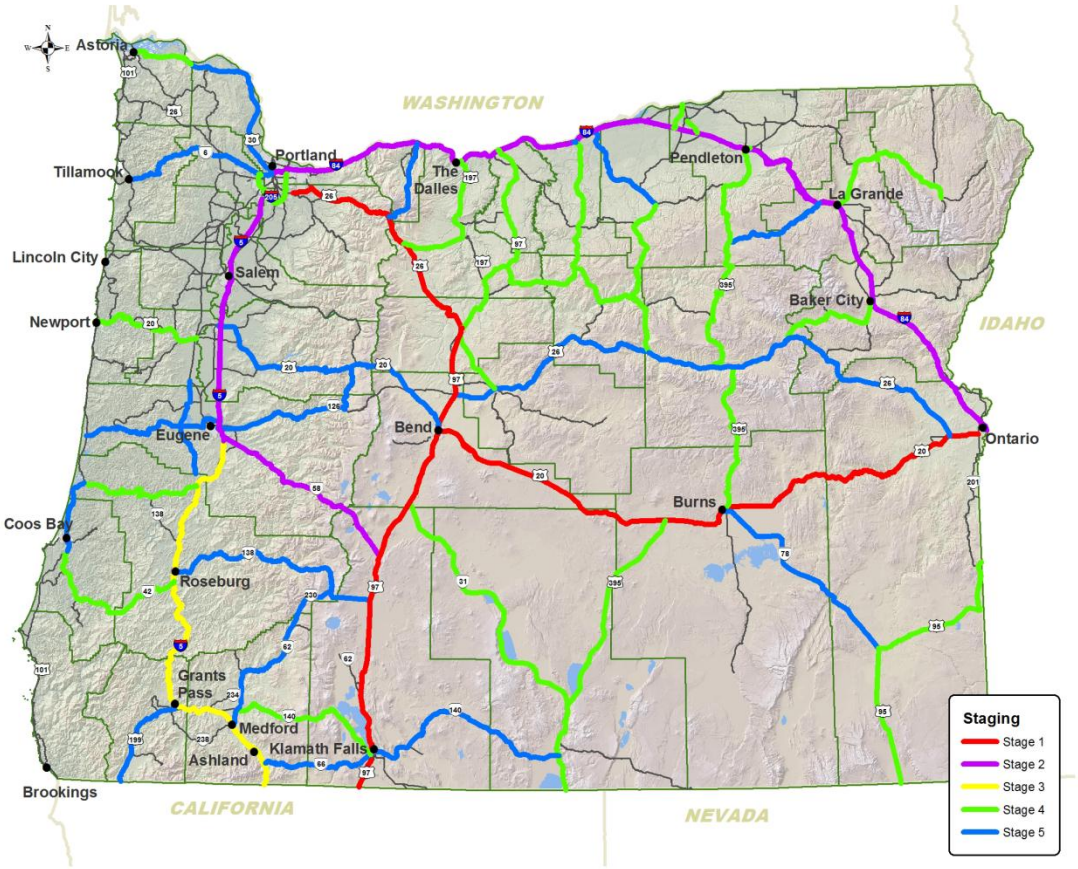
## Bridge Conditions

Under assumptions for the Current Revenues / Deterioration Scenario, bridge preservation projects are anticipated to be allocated $50 million per year over the next 20 years (in today's dollars). This level is about two-thirds of the budget for bridge projects a decade ago, before accounting for higher construction costs due to inflation. This equates to a $1 billion budget over the next 20 years. Currently, ODOT estimates roughly 900 bridges on State maintained highways will need some level of preservation work (either a rehabilitation or complete reconstruction) over the next 20 years. The work for these 900 bridges is estimated to cost somewhere between 4 and 5 billion dollars (in current dollars), 4 to 5 times the current assumed available funding.

With the *Current Revenue / Deterioration Scenario* budget ODOT intends to do its best to preserve the bridges along the following facilities and maintain operations as they are today:

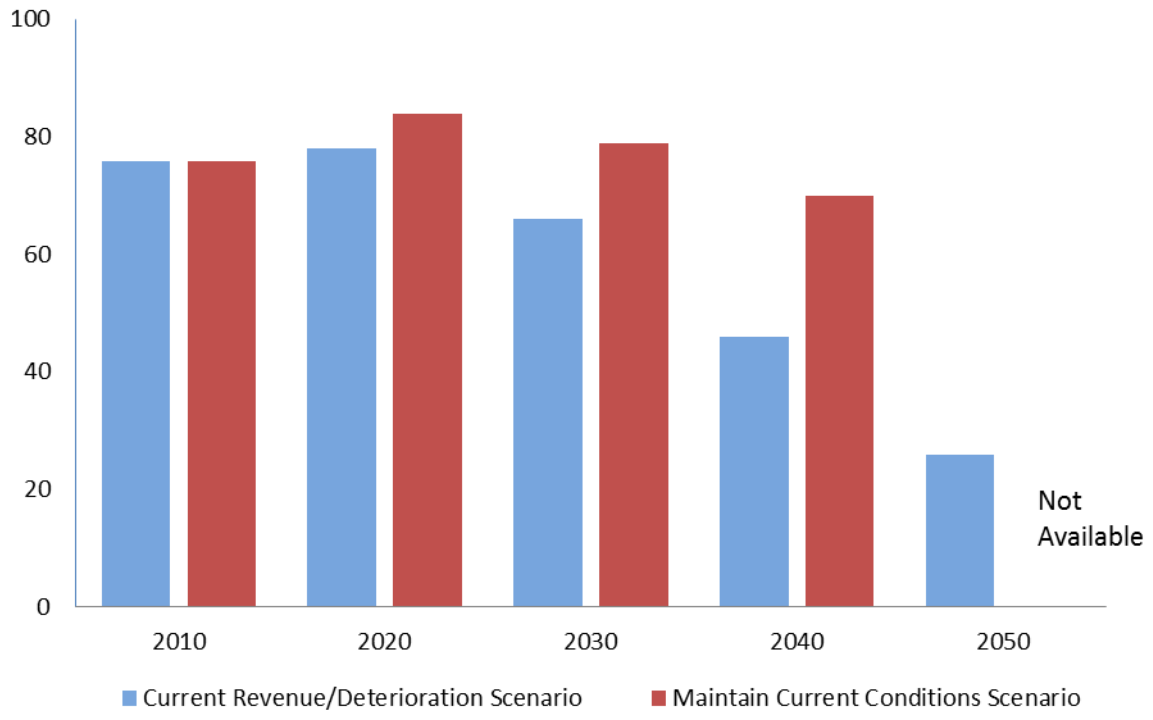
- The Interstate Routes (I-5, I-84, I-82, I-405, and I-205),
- Most of the Stage 1-4 OTIA routes as identified below in Figure 12, and
- Limiting permanent lane closures on state maintained highways.

**Figure 12 OTIA Routes by Stage**



Approximately 600 of the 900 identified bridges would not receive funding under the *Current Revenue / Deterioration Scenario*. Of these 600, approximately 350 would require some level of weight restriction by 2035. Weight restrictions are anticipated to be lower than 80,000 pounds, meaning the most common configuration of heavy tractor-trailer combination trucks on Oregon's highway could not travel over weight restricted bridges without reducing their load to meet the given weight restriction. Thus, bridge weight restrictions impact the flow of goods in Oregon; implications of which are discussed in other sections of this report. Starting as early as 2020 weight restrictions would be applied to bridges deemed deficient, increasing in severity over time if major repairs are not made. By 2035, 357 bridges are expected to have weight restrictions. By 2045 another 250 bridges requiring restrictions are expected, with the number steadily increasing beyond 2045. Figure 13 reports the proportion of non-stressed bridges[11] forecast on the state highway system for 2010 to 2050 for the *Current Revenue / Deterioration Scenario* and 2010 to 2040 for the *Maintain Current Conditions Scenario*. There is an increasing proportion of distressed bridges over time in the *Current Revenue / Deterioration Scenario* compared to the *Maintain Current Conditions Scenario*. Under the Scenario, no additional bridge restrictions on state highways are anticipated.

**Figure 13 Forecast Proportion of Bridges Categorized as Non-Distressed by Scenario**




Similar to pavement there is a significant cost to postponing bridge repairs. Of the approximately 600 state maintained bridges not addressed in the *Current Revenue / Deterioration Scenario*, roughly 275 of these are

[11] Proportion of the 2681 state owned Nation Bridge Inventory (NBI) bridges

scoped as rehabilitation projects. Rehabilitation prolongs the life of a bridge as long as possible and puts off the larger cost of complete reconstruction. If these 275 bridges receive rehabilitation work as needed, the cost of the work is estimated as just over $1 billion dollars over 20 years (in current dollars). This amount is included in the $4-5 billion need mentioned earlier, but this need is not included under the current funding assumptions represented in the *Current Revenue / Deterioration Scenario*. If these bridges do not receive needed rehabilitation, they will eventually require weight restriction, and all of which would be restricted by 2045. Delayed rehabilitation would also increase the frequency of reactive work which would lead to further delays to the traveling public. Depending on the nature of the needed repairs, reconstruction may require full bridge closures to access the stressed areas to repair, e.g. repairing a concrete bridge element requires concrete cure time. The cost of restoring an under-maintained bridge to normal operation is much greater than the cost of properly maintaining them over time.

After 20 years of operating at current forecast funding levels used for the *Current Revenue / Deterioration Scenario*, it is estimated the state would pay between $5.4 billion to $7.2 billion (current dollars) to return distressed bridges to conditions similar to levels existing today. For an additional $180 million per year, which totals an extra $3.6 billion over the next 20 years, the state could preserve bridges at current levels for half to two thirds of the cost, avoiding $1.4 billion to $3.2 billion in extra costs in the future.

## Impact on Priorities for Maintenance

The current ODOT highway maintenance budget meets just over 80 percent of expected need. This shortfall in resources requires prioritization of spending, which involves a complex balancing of needs with fiscal limitations. In general, the prioritization approach places an emphasis on budgeting for unplanned emergencies and less planned preventative work designed to minimize infrastructure life cycle costs. Higher functional class facilities, such as interstates and significant state highways, rise to the top of the priority list, while maintenance on district-level facilities is delayed. Such delays have safety implications likely to end up being addressed through the use of unplanned emergency funds.

Currently the maintenance budget is forecast to increase 3% a year. By 2025 the maintenance budget is estimated to be $325 million per year and the modernization/enhance-it budget would be zero. The higher maintenance budget is somewhat misleading. While current needs are estimated as $300 million per year, the delayed increase in the maintenance budget is not enough to meet growing needs over time. Pavement and Bridge preservation funding shortfalls are causing the maintenance needs to rise at increasing rates. Work funded under the pavement and bridge preservation programs will shift to maintenance activity in a prioritized and reactive manner. Hundreds of additional miles of pavement and bridge structures will need to be treated with spot fixes as unplanned emergencies occur, instead of planned preservation and maintenance projects designed to minimize the overall life cycle costs of the system.

The following are further examples of shifting maintenance priorities likely to occur over the next 20 years under ODOT's current funding forecast:

- Maintenance crews would become more reactive to pavement maintenance than currently. As ODOT staff spend more time on reactive maintenance, other work functions will either be sub-contracted or dropped,
- Current maintenance activity may be reduced; for example sweeping designed to maintain conditions for use by motorcycles and bicycles,
- Preventative chip seal and other pre-emptive activity, such as protective bridge coatings, would likely be reduced; as pre-emptive programs are reduced the system will deteriorate faster and require more funds in the future to return conditions to levels existing currently,
- As bridge maintenance declines more load postings will be necessary,
- More roads will be posted as rough-roads with potential speed reductions, vehicle maintenance and operation costs will rise for highway users – auto, commercial and freight users,
- Reactive unplanned maintenance money put into bridges to keep them safe and operating are short-term uneconomical expenditures; reactive expenditures don't solve the fundamental construction issues; the efficient, least cost manner to maintain infrastructure is to conduct planned rehabilitation projects,

## Conclusion

If the Oregon highway and bridges are preserved and maintain at current condition levels, over 100 thousand more jobs are forecast in 20 years than expected if conditions decline under the current ODOT funding forecast. Over $94 billion in additional Oregon gross domestic product is forecast if conditions are maintained at current levels. Clearly, the return on investment in the highway system supports a good business case for preserving current conditions.

Few dispute the value of a well-functioning transportation system. The challenges faced by Oregon are occurring across the nation. Recently, The White House published a report detailing the economic benefits of transportation investment (see callout box below).[12] Oregon has a history of managing the system efficiently. This system supported a successful economy that has weathered changes to our industrial structure and developed a growing export sector. The highways and bridges across the state serve as a foundation supporting economic activity. In order to maintain our place in the global market, Oregon needs to preserve our competitive advantages and support continued economic prosperity.

[12] "An Economic Analysis of Transportation Infrastructure Investment," July 2014, prepared by the National Economic Council and the President's Council of Economic Advisers. http://www.whitehouse.gov/sites/default/files/docs/economic_analysis_of_transportation_investments.pdf

From "AN ECONOMIC ANALYSIS OF TRANSPORTATION INFRASTRUCTURE INVESTMENT", White House Council of Economic Advisors, July 2014

A high quality transportation network is vital to a top performing economy. Investments by previous generations of Americans … were instrumental in putting the country on a path for sustained economic growth, productivity increases, an unrivalled national market for good and services, and international competitiveness. …

A well-performing transportation network keeps jobs in America, allows businesses to expand, and lowers prices on household goods to American families. It allows businesses to manage their inventories and transport goods more cheaply and efficiently as well as access a variety of suppliers and markets for their products, making it more cost-effective for manufacturers to keep production in or move production to the United States. American families benefit too: as consumers, from lower priced goods; and as workers, by gaining better access to jobs.

The economic benefits of smart infrastructure investment are long-term competitiveness, productivity, innovation, lower prices, and higher incomes, while infrastructure investment also creates many thousands of American jobs in the near-term.

The transportation system is a multi-billion dollar asset requiring long range planning and strategic investment in order to provide the highest level of service for the lowest cost. A deteriorating highway system increases the cost of travel and shipping, risking Oregon's competitive advantage in the global marketplace. Over the course of 20 years, the impacts of a deteriorating highway system will be significant to Oregon, but not immediately apparent in the short run. Looking beyond 20 years the system impacts will be large and costly to resolve in terms of time and investment. By delaying preservation and maintenance investment now, Oregon risks transportation dependent industries leaving the state, taking away high-wage jobs and affecting the overall standard of living. By the time Oregon could catch up and repair the system, the economy could be structurally different; unlikely to return to the full potential expected now given current industry structure and highway conditions.

While the cost of preserving and maintaining roads is high for agencies, the cost of operating and maintaining vehicles is greater for users driving on deteriorating infrastructure. It is more affordable to users to pay a little more in user fees in order to avoid paying a lot more in vehicle operating costs, while maintaining access to jobs similar to those available today.

Oregon auto taxes and fees are the lowest in the nation according to Bankrate.com's recent Car Cost Index[13] which lists annual costs of car ownership for all 50 U.S. states. Table 5 provides the 5 highest and lowest cost states for car ownership in 2013. Oregon's annual average cost for car ownership is about 31 percent lower than the national average. Oregon costs for vehicle repairs, gas and insurance are between 5 and 8 percent lower

[13] http://www.bankrate.com/finance/auto/car-ownership-costs-by-state.aspx and summarized by Oregon Live: http://www.oregonlive.com/commuting/index.ssf/2013/08/oregon_the_least_expensive_sta.html#incart_river

than the national averages. The largest difference in Oregon vehicle costs is for taxes and fees, which Bankrate.com estimated to be $157 a year, about 85 percent lower than the national average of $1,085.

**Table 5 Bankerate.com: Annual Car-Ownership Costs by State 2013: Five Highest and Five Lowest Cost States (U. S. dollars)**

| Rank | State | Repairs | Taxes/Fees | Gasoline | Insurance | Total |
|---|---|---|---|---|---|---|
| 1 | Georgia | 385 | 1952 | 1129 | 767 | 4233 |
| 2 | California | 390 | 1809 | 980 | 786 | 3966 |
| 3 | Wyoming | 324 | 1341 | 1643 | 630 | 3938 |
| 4 | Rhode Island | 371 | 1717 | 826 | 999 | 3913 |
| 5 | Nevada | 364 | 1741 | 811 | 970 | 3886 |
| : | | | | | | |
| 46 | Indiana | 329 | 558 | 1190 | 621 | 2698 |
| 47 | Montana | 360 | 521 | 1118 | 661 | 2660 |
| 48 | South Dakota | 312 | 415 | 1092 | 524 | 2343 |
| 49 | Alaska | 341 | 202 | 771 | 914 | 2227 |
| **50** | **Oregon** | **380** | **157** | **942** | **724** | **2204** |
| | **50 State Average** | 353 | 1058 | 1028 | 762 | 3201 |

As of January 2014, Oregon automobile-related taxes are the lowest among our neighboring western states. Table 6 presents a summary comparison of seven western states' taxes, including Oregon.[14] Oregon taxes include gas tax, registration fees, title fees and other related fees. Montana's total taxes are very similar to Oregon, with the exception of ad valorem taxes. Idaho, Utah, Nevada, Washington and California generate auto sales taxes larger than the total amount of Oregon taxes. California, Washington, and Nevada have the highest state gas excise taxes and gas sales and local option taxes.

**Table 6 Summary Comparison of 7 Western States Automobile-Related Taxes, January 2014**

| Tax (cents per gallon units) | Oregon | Montana | Idaho | Utah | Nevada | Washington | California |
|---|---|---|---|---|---|---|---|
| State Gas Excise Tax | 30.1 | 27.0 | 26.0 | 25.0 | 24.8 | 37.6 | 40.9 |
| Gas Sales & Local Option Taxes | 1.0 | 0.0 | 0.0 | 0.0 | 14.2 | 0.0 | 16.6 |
| Registration Fees | 8.6 | 8.3 | 8.6 | 13.3 | 6.6 | 16.9 | 13.8 |
| Ad Valorem Taxes | 0.0 | 8.5 | 0.0 | 10.0 | 13.8 | 1.6 | 6.2 |
| Auto Sales Taxes | 0.0 | 0.0 | 48.0 | 54.8 | 64.0 | 72.0 | 68.0 |
| Title and Related Fees | 3.9 | 0.6 | 0.7 | 0.3 | 1.4 | 1.9 | 0.9 |
| Total Cents per Gallon | 43.6 | 45.2 | 83.3 | 103.4 | 124.8 | 130.0 | 146.4 |

[14] "Comparison of Automobile-Related Taxes, 2014" ODOT http://www.oregon.gov/ODOT/TD/EA/reports/2014_WesternStatesTaxes.pdf

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# Appendix A – Oregon Statewide Integrated Model 2 (SWIM2) Description

**What it is**: a data driven forecast model designed to represent the Oregon economy with respect to land-use and transportation by simulating the activity and market exchanges made by people and businesses. Household and business location decisions are simulated, as well as the travel generated by activities - such as commuting to work, purchasing commodities for industrial production and transporting final goods to markets within Oregon and outside of the state. It is designed for statewide and regional long range transportation planning and policy analysis. Information from the SWIM is designed to inform other modeling tools, such as metropolitan planning organization travel models, freight models, and regional studies.

**Why it is important**: SWIM is designed to serve as a testing ground to evaluate "what if" scenarios related to areas we can control, such as public policy related to taxes, fees and land use rules; areas we cannot control such as rising oil prices, national recessions, and population growth; and other issues impacting decisions related to the Oregon transportation system.

**Why it was developed**: In the early 1990's there was federal interest in developing tools that integrate land use, transportation, economics and the environment. The Federal Intermodal Surface Transportation Efficiency Act (ISTEA, 1991) and the 1990 Clean Air Act Amendments were enacted so local and state agencies could do a better job of coordination on land use and transportation decisions. In response to these Acts, the level and type of analysis and information requested from modeling and analysis tools and methods changed nationally.

Oregon's response to these new mandates was formation of the Oregon Modeling Improvement Program in 1994. The program was implemented cooperatively, led by the Oregon Modeling Steering Committee, which includes membership of over 15 public agency partners. The Committee seeks to improve state-of-the-practice and promote state-of-the-art modeling in Oregon and serve as a consensus forum and support group to coordinate land-use-transportation modeling efforts of federal, state, regional and local agencies. The SWIM model development has included extensive technical review by national and international experts.

**How it has been used**: The SWIM has been used for a variety of studies:

**Seismic Bridge Options Economic Impact Analysis (2013):** SWIM was used to produce high level estimates of avoidable economic impacts associated with a major seismic event on the Cascadia Subduction Zone. The analysis provided a general sense of the magnitude and direction of avoidable economic impacts compared to the investment needed for a pre-emptive mitigation program. Findings indicated investing $1.8 billion toward seismic mitigation would avoid the loss of $84 billion in Oregon gross domestic product, which results in a benefit/cost ratio of 46. Accounting for the estimated 12%

chance of the earthquake occurring within the next 50 years adjusts the benefit/cost figure to 5.6, further indicating mitigation investment is a sound business decision for Oregon.[15]

**Oregon Freight Plan (2010)**: SWIM was used to evaluate the variation in statewide and regional economic activity and commodity flow in order to evaluate uncertainty associated with economic volatility on alternative Freight Plan strategies. This information enabled decision makers to better assess the robustness of freight strategies and avoid the creation of barriers prohibiting the freight industry from reacting nimbly to economic change.[16]

**Oregon Transportation Plan Update (2005):** SWIM was used for scenario analysis designed to develop a long range plan that is effective and relevant under conditions of uncertainty in several key areas. Two sensitivity scenarios were used to evaluate impacts of higher fuel prices and more relaxed land use policies affecting available land for future development on urban boundaries and rural areas. Four policy scenarios provided information evaluating different funding options, program priorities and other related issues.[17] This modeling analysis earned ODOT an FHWA/FTA Transportation Planning Excellence Award.[18]

**Economic & Bridge Options Report (2003)**: SWIM was used to examine the economic impacts of expected bridge weight limits throughout the state due to increasing number of cracking problems on aging bridges. The model simulated the response of trucks to bridge weight restrictions and quantified the impacts on statewide and regional industry production and jobs, transportation costs and changes in travel and land use patterns. The model estimated Oregon's bridge problem could cost the state as much as $123 billion in lost production and 88,000 forfeited jobs over the next 25 years.[19]

**Newberg-Dundee Bypass (2002)**: SWIM was used to evaluate the potential for a bypass to induce additional development in Yamhill County. A concern regarding induced growth associated with the bypass has been a significant issue in the bypass planning process. The SWIM was used successfully to evaluate the nature and general magnitude of induced growth effects. The results were very important to the land use exceptions process and a subsequent court appeal.[20]

**Eastern Oregon Freeway Alternative (2001):** prompted by a legislative directive (HB3090) to ODOT to study the construction of a new freeway, SWIM was used to evaluate whether population and traffic growth would be diverted from the Willamette Valley to regions east of the Cascades. Analysis revealed a new freeway would not shift growth away from the Willamette Valley.[21]

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[15] http://www.oregon.gov/ODOT/TD/TP/docs/Statewide/CascadiaSubductionZoneEarthquake_EconomicImpact_2012.pdf
[16] http://www.oregon.gov/ODOT/TD/TP/docs/ofp/ofpmodelingmemo.pdf
[17] http://www.oregon.gov/ODOT/TD/TP/docs/otp/analysis.pdf
[18] http://www.oregon.gov/ODOT/TD/TP/docs/Statewide/2008_OTP_award.pdf
[19] http://www.oregon.gov/ODOT/TD/TP/docs/statewide/econbridgerpt.pdf
[20] http://www.oregon.gov/ODOT/TD/TP/docs/statewide/newbergdundee.pdf
[21] http://www.oregon.gov/ODOT/TD/TP/docs/statewide/hb3090.pdf

**Willamette Valley Livability Forum (2001)**: This was the first analysis conducted using the newly developed Statewide Integrated Model. The Forum initiated a comprehensive regional visioning process for future land use and transportation in the Willamette Valley. Modeled scenarios varied by land use, road networks, public transit networks and mileage tax. By modeling various combinations of policy options, decision-makers identified likely conditions which influenced adopted policies shaping the Willamette Valley for future generations. [22]

**Model design features:** The Statewide Model is described as an "integrated" model because the sub-models are interconnected. Information is shared back and forth between the sub-models, mimicking the reactive and interactive behaviors observed in the real world. The model is designed to represent how people and businesses share information and exchange goods and services based on prices and location. The integrated modular design better represents real-world conditions and activity, but requires an immense amount of data, significant development time, powerful computing capabilities and trained staff. For these two reasons, very few states have a statewide economic, land use and transportation model like Oregon's.

The Oregon Statewide Integrated Model consists of specialized sub-models that interconnect with each other:

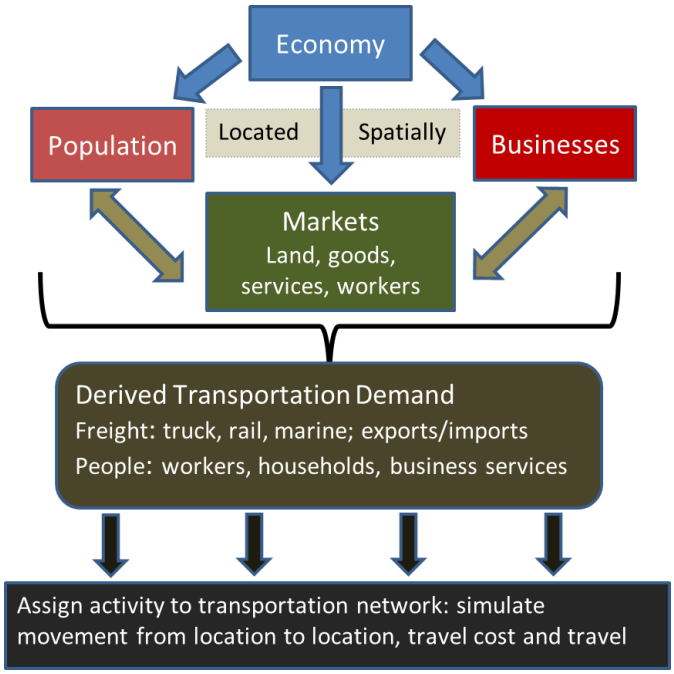
- **Economic Model**: based on the official state revenue forecast prepared by the Department of Administrative Services, Office of Economic Analysis; provides statewide totals for employment by industry, inflation rate, imports and exports, unemployment rate,
- **Population Synthesizer**: simulates a population with observed Oregon characteristics such as age, household size, household location, income, occupation, worker/non-worker/student status,
- **Production Location Model**: simulates where businesses locate, the commodities they purchase to use as production inputs, number and type of workers hired, the amount of floorspace they purchase/lease for their production facility, and production of goods and services sold based on market prices
- **Land Development Model:** identifies land availability based on floorspace prices and vacancy rates for firms and households to rent or purchase,
- **Person Travel**: simulates person activity for a typical weekday for the people simulated by the Population Synthesizer, activity involving travel is assigned a travel mode such as auto, transit, or rail,
- **Commercial Goods Transport**: simulates how commodities are moved as freight by different modes of transport, such as marine, rail, and truck for a typical weekday
- **External Goods Transport**: simulates freight movement for exports, imports and through the state,

[22] http://www.oregon.gov/ODOT/TD/TP/docs/statewide/smap.pdf

- **Transport Model**: assigns trips to a computer network, trips generated in the Person Travel Model, Commercial Goods Transport model, External Goods Transport model

  Figure A illustrates the interaction and connections between the different activities represented within the model via the specialized sub-models.

Figure A: SWIM2 Schematic




SWIM is used for scenario analysis. A reference scenario is developed to represent current conditions or policy most likely for a 20 year planning horizon. Alternative scenarios are developed to represent the "what if" areas of analysis. This way, a range of potential futures are identified and implications associated with uncertainty can be assessed. Typically, SWIM is used to evaluate potential impacts on employment and gross state product. Other elements of the model may be reported, but the level of reporting depends on the level of detailed data prepared for the model setup. The full model documentation is available online here:
http://www.oregon.gov/ODOT/TD/TP/docs/statewide/swim2.pdf

# Appendix B

Tables used for estimating potential impacts of pavement condition on highway users were taken from "NCHRP Report 720 – Estimating the Effects of Pavement Condition on Vehicle Operating Costs," 2012. The International Roughness Index (IRI) used in the tables is a pavement roughness measurement was developed as part of the World Bank Highway Development and Management System. It allows consistent measurement and evaluation of the pavement surface factors influencing vehicle operating costs.

**Table 7-1. Effect of roughness on fuel consumption.**

| | | Fuel Consumption | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Base (mL/km) | Adjustment Factors from the Base Value | | | | | Base (mpg) | Adjustment Factors from the Base Value | | | | |
| | | IRI (m/km) | | | | | | IRI (m/km) | | | | | |
| Speed | Vehicle Class | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 56 km/h (35 mph) | Medium car | 70.14 | 1.03 | 1.05 | 1.08 | 1.10 | 1.13 | 33.53 | 0.97 | 0.95 | 0.93 | 0.91 | 0.88 |
| | Van | 76.99 | 1.01 | 1.02 | 1.03 | 1.04 | 1.05 | 30.55 | 0.99 | 0.98 | 0.97 | 0.96 | 0.95 |
| | SUV | 78.69 | 1.02 | 1.05 | 1.07 | 1.09 | 1.12 | 29.89 | 0.98 | 0.95 | 0.93 | 0.92 | 0.89 |
| | Light truck | 124.21 | 1.01 | 1.02 | 1.04 | 1.05 | 1.06 | 18.94 | 0.99 | 0.98 | 0.96 | 0.95 | 0.94 |
| | Articulated truck | 273.41 | 1.02 | 1.04 | 1.07 | 1.09 | 1.11 | 8.60 | 0.98 | 0.96 | 0.93 | 0.92 | 0.90 |
| 88 km/h (55 mph) | Medium car | 83.38 | 1.03 | 1.05 | 1.08 | 1.10 | 1.13 | 28.21 | 0.97 | 0.95 | 0.93 | 0.91 | 0.88 |
| | Van | 96.98 | 1.01 | 1.02 | 1.03 | 1.04 | 1.05 | 24.25 | 0.99 | 0.98 | 0.97 | 0.96 | 0.95 |
| | SUV | 101.29 | 1.02 | 1.04 | 1.07 | 1.09 | 1.11 | 23.22 | 0.98 | 0.96 | 0.93 | 0.92 | 0.90 |
| | Light truck | 180.18 | 1.01 | 1.02 | 1.03 | 1.04 | 1.05 | 13.05 | 0.99 | 0.98 | 0.97 | 0.96 | 0.95 |
| | Articulated truck | 447.31 | 1.02 | 1.03 | 1.05 | 1.06 | 1.08 | 5.26 | 0.98 | 0.97 | 0.95 | 0.94 | 0.93 |
| 112 km/h (70 mph) | Medium car | 107.85 | 1.02 | 1.05 | 1.07 | 1.09 | 1.12 | 21.81 | 0.98 | 0.95 | 0.93 | 0.92 | 0.89 |
| | Van | 128.96 | 1.01 | 1.02 | 1.03 | 1.03 | 1.04 | 18.24 | 0.99 | 0.98 | 0.97 | 0.97 | 0.96 |
| | SUV | 140.49 | 1.02 | 1.04 | 1.06 | 1.08 | 1.10 | 16.74 | 0.98 | 0.96 | 0.94 | 0.93 | 0.91 |
| | Light truck | 251.41 | 1.01 | 1.02 | 1.02 | 1.03 | 1.04 | 9.36 | 0.99 | 0.98 | 0.98 | 0.97 | 0.96 |
| | Articulated truck | 656.11 | 1.01 | 1.02 | 1.04 | 1.05 | 1.06 | 3.58 | 0.99 | 0.98 | 0.96 | 0.95 | 0.94 |

**Table 7-2. Effect of roughness on tire wear rates.**

| Speed | Vehicle Class (number of wheels) | Tire Wear | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Baseline Conditions (%/km) | Baseline Conditions (%/mi) | Adjustment Factors from the Baseline Conditions | | | | |
| | | IRI (m/km) | | | | | | |
| | | 1 | | 2 | 3 | 4 | 5 | 6 |
| 56 km/h (35 mph) | Medium car (4) | 0.0013 | 0.0021 | 1.01 | 1.01 | 1.02 | 1.02 | 1.03 |
| | Van (4) | 0.0011 | 0.0017 | 1.00 | 1.01 | 1.01 | 1.02 | 1.02 |
| | SUV (4) | 0.0011 | 0.0017 | 1.01 | 1.02 | 1.03 | 1.04 | 1.05 |
| | Light truck (4) | 0.0012 | 0.0020 | 1.01 | 1.02 | 1.03 | 1.04 | 1.05 |
| | Articulated truck (18) | 0.0006 | 0.0010 | 1.01 | 1.01 | 1.02 | 1.02 | 1.03 |
| 88 km/h (55 mph) | Medium car (4) | 0.0014 | 0.0022 | 1.01 | 1.02 | 1.03 | 1.04 | 1.05 |
| | Van (4) | 0.0013 | 0.0021 | 1.01 | 1.01 | 1.02 | 1.03 | 1.04 |
| | SUV (4) | 0.0013 | 0.0021 | 1.01 | 1.03 | 1.05 | 1.06 | 1.08 |
| | Light truck (4) | 0.0018 | 0.0029 | 1.01 | 1.02 | 1.04 | 1.05 | 1.06 |
| | Articulated truck (18) | 0.0007 | 0.0012 | 1.01 | 1.02 | 1.03 | 1.04 | 1.05 |
| 112 km/h (70 mph) | Medium car (4) | 0.0015 | 0.0025 | 1.01 | 1.03 | 1.04 | 1.06 | 1.08 |
| | Van (4) | 0.0018 | 0.0028 | 1.01 | 1.02 | 1.03 | 1.04 | 1.04 |
| | SUV (4) | 0.0017 | 0.0027 | 1.02 | 1.04 | 1.06 | 1.08 | 1.10 |
| | Light truck (4) | 0.0029 | 0.0046 | 1.01 | 1.02 | 1.04 | 1.05 | 1.06 |
| | Articulated truck (18) | 0.0009 | 0.0015 | 1.01 | 1.02 | 1.03 | 1.04 | 1.06 |

**Table 7-3. Effect of roughness on repair and maintenance costs.**

| Speed | Vehicle Class | Repair and Maintenance Costs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Average* ($/km) | Average* ($/mi) | Baseline Conditions ($/km) | Baseline Conditions ($/mi) | Adjustment Factors from the Baseline Conditions | | | | |
| | | | | IRI (m/km) | | | | | | |
| | | | | 1 | | 2 | 3 | 4 | 5 | 6 |
| 56 km/h (35 mph) | Medium car | 0.040 | 0.064 | 0.015 | 0.024 | 1.0 | 1.0 | 1.1 | 1.4 | 1.7 |
| | Van | 0.052 | 0.083 | 0.020 | 0.032 | 1.0 | 1.0 | 1.1 | 1.4 | 1.7 |
| | SUV | 0.052 | 0.083 | 0.020 | 0.032 | 1.0 | 1.0 | 1.2 | 1.7 | 2.3 |
| | Light truck | 0.058 | 0.092 | 0.021 | 0.034 | 1.0 | 1.0 | 1.2 | 1.7 | 2.2 |
| | Articulated truck | 0.124 | 0.199 | 0.046 | 0.074 | 1.0 | 1.0 | 1.1 | 1.5 | 1.8 |
| 88 km/h (55 mph) | Medium car | 0.040 | 0.064 | 0.019 | 0.030 | 1.0 | 1.0 | 1.1 | 1.4 | 1.7 |
| | Van | 0.052 | 0.083 | 0.025 | 0.040 | 1.0 | 1.0 | 1.1 | 1.4 | 1.7 |
| | SUV | 0.052 | 0.083 | 0.025 | 0.040 | 1.0 | 1.0 | 1.2 | 1.7 | 2.3 |
| | Light truck | 0.058 | 0.092 | 0.029 | 0.046 | 1.0 | 1.0 | 1.2 | 1.7 | 2.2 |
| | Articulated truck | 0.124 | 0.199 | 0.063 | 0.101 | 1.0 | 1.0 | 1.1 | 1.5 | 1.8 |
| 112 km/h (70 mph) | Medium car | 0.040 | 0.064 | 0.023 | 0.036 | 1.0 | 1.0 | 1.1 | 1.4 | 1.7 |
| | Van | 0.052 | 0.083 | 0.030 | 0.047 | 1.0 | 1.0 | 1.1 | 1.4 | 1.7 |
| | SUV | 0.052 | 0.083 | 0.030 | 0.047 | 1.0 | 1.0 | 1.2 | 1.7 | 2.3 |
| | Light truck | 0.058 | 0.092 | 0.035 | 0.057 | 1.0 | 1.0 | 1.2 | 1.7 | 2.2 |
| | Articulated truck | 0.124 | 0.199 | 0.077 | 0.123 | 1.0 | 1.0 | 1.1 | 1.5 | 1.8 |

1 m/km = 63.4 in./mi
*These costs are unit repair costs related only to damage from vibrations.

## Table 7-5. Effect of roughness on vehicle operating costs.

| Speed | Vehicle Class | Vehicle Operating Costs | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Baseline Conditions (¢/km) | Baseline Conditions (¢/mi) | Adjustment Factors from the Baseline Conditions | | | | |
| | | IRI (m/km) | | | | | | |
| | | 1 | | 2 | 3 | 4 | 5 | 6 |
| 56 km/h (35 mph) | Medium car | 8.8 | 14.0 | 1.02 | 1.04 | 1.08 | 1.15 | 1.22 |
| | Van | 10.0 | 16.1 | 1.01 | 1.02 | 1.05 | 1.11 | 1.18 |
| | SUV | 10.2 | 16.3 | 1.02 | 1.03 | 1.09 | 1.20 | 1.34 |
| | Light truck | 14.9 | 23.9 | 1.01 | 1.02 | 1.06 | 1.13 | 1.22 |
| | Articulated truck | 36.1 | 57.7 | 1.02 | 1.03 | 1.07 | 1.13 | 1.19 |
| 88 km/h (55 mph) | Medium car | 10.5 | 16.8 | 1.02 | 1.04 | 1.08 | 1.15 | 1.22 |
| | Van | 12.6 | 20.2 | 1.01 | 1.01 | 1.05 | 1.11 | 1.17 |
| | SUV | 13.0 | 20.8 | 1.02 | 1.03 | 1.09 | 1.20 | 1.32 |
| | Light truck | 21.6 | 34.6 | 1.01 | 1.02 | 1.05 | 1.12 | 1.20 |
| | Articulated truck | 56.7 | 90.7 | 1.01 | 1.02 | 1.05 | 1.10 | 1.15 |
| 112 km/h (70 mph) | Medium car | 13.3 | 21.3 | 1.02 | 1.03 | 1.07 | 1.14 | 1.21 |
| | Van | 16.5 | 26.5 | 1.01 | 1.01 | 1.04 | 1.10 | 1.16 |
| | SUV | 17.6 | 28.2 | 1.01 | 1.03 | 1.08 | 1.18 | 1.29 |
| | Light truck | 30.1 | 48.1 | 1.01 | 1.01 | 1.04 | 1.10 | 1.17 |
| | Articulated truck | 81.2 | 130.0 | 1.01 | 1.02 | 1.04 | 1.08 | 1.13 |

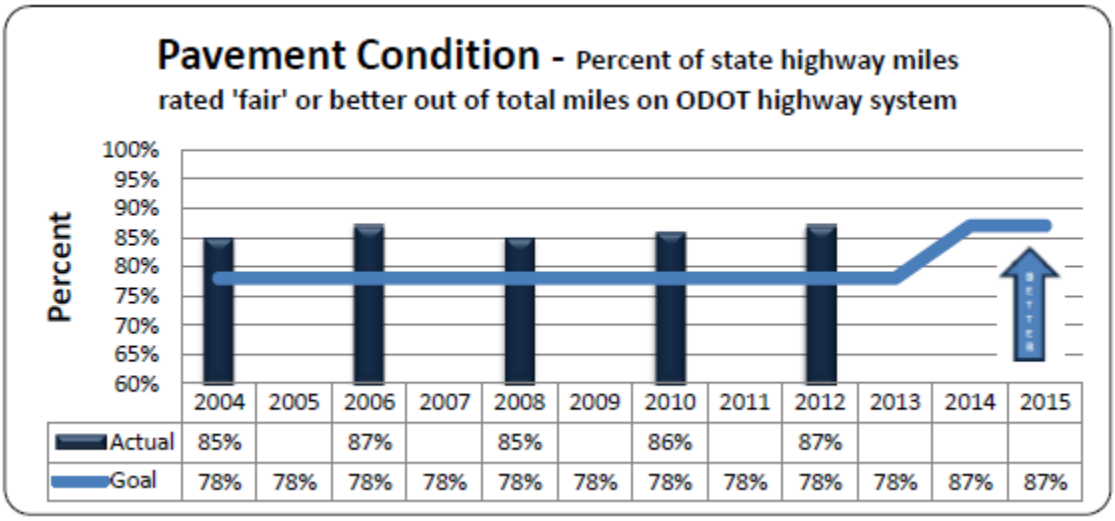
1 m/km = 63.4 (in./mi)

# Appendix C

## Lower-Volume State Highway Deterioration Scenario

Between 1976 and 1984 the proportion of pavement with poor or worse condition ratings ranged from 43 to 58 percent. This prompted an injection of funding aimed at improving pavement conditions. Since then, Oregon has done an excellent job improving and maintaining pavement conditions. Over the last decade ODOT has consistently met or exceeded pavement condition goals, as illustrated in Figure C1.

Figure C1




| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual | 85% | | 87% | | 85% | | 86% | | 87% | | | |
| Goal | 78% | 78% | 78% | 78% | 78% | 78% | 78% | 78% | 78% | 78% | 87% | 87% |

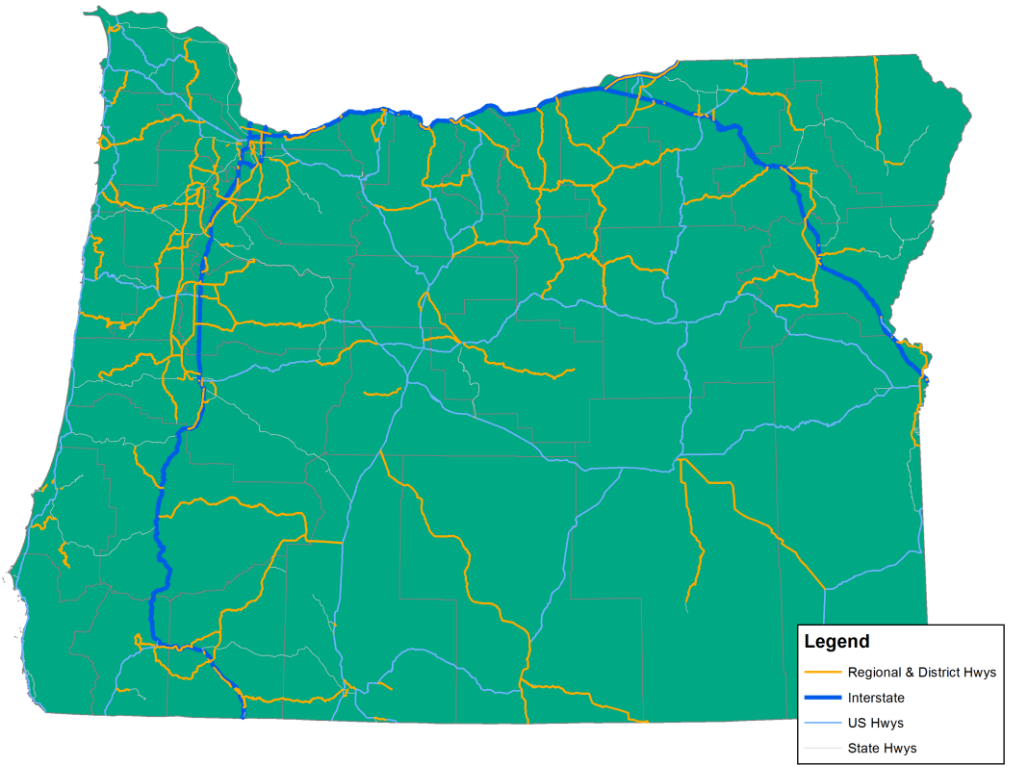
Because a majority of Oregon state highway pavement is in fair or better condition, the analysis in this report assumed the highway network will continue to operate at roughly the same speeds and provide the same functionality as seen today. There would be significant increases in cracks, rutting, patchwork, and potholes, but highway users would still be able to travel highways in poor condition at roughly the same speeds as observed today for close to 20 years. The main report briefly discusses the impacts of pavement condition on vehicle operating costs, but they are not fully represented in the analysis, especially the effects on moving freight. The analysis assumes pavement will not completely deteriorate over 20 years of under investing. The high level economic analysis presented in this report primarily evaluates the economic impacts of bridge weight restrictions, since they have the greatest impact on commodity flows in trucks.

However, the analysis team acknowledges there comes a time when under investment in the system will result in pavement deterioration impacting travel speeds. In time, higher speed paved roads existing today will be posted at much lower speeds in the future if investment is not put into maintaining the paved surface. High speed travel on poor pavement causes accidents, vehicle damage, and other incidents. Developing specific schedules of pavement deterioration is beyond the scope of this analysis. However, high-level estimates were developed of impacts associated with maintaining the interstates and higher volume state highways and allowing lower volume/ lower functional class roads deteriorate due to lack of funding. This analysis is peripheral

to the main report and represents rough estimates of potential impacts occurring over the long run, beyond a 20 year planning period. The purpose of this side-analysis is to consider implications associated with prioritizing maintenance of higher volume highways letting lower functional roads deteriorate.

One modeling scenario using SWIM was developed to estimate the economic impacts of posting speeds for all regional and district highways as if they were gravel surfaces. Figure C2 below illustrates the regional and district highways assessed in the analysis.

**Figure C2 Regional and District Highways Included in Scenario**




Results indicate there is potential to lose an additional 30,000 jobs above and beyond the economic losses identified in Current Revenues / Deterioration Scenario and *Maintain Current Conditions Scenario* analysis. Allowing the regional and district highways to deteriorate over time negatively impacts the Willamette Valley and Eastern Oregon regions. Figure C3 illustrates the estimated impacts. Results suggest as pavement condition deteriorates overtime, areas of the state relatively unaffected by bridge weight restrictions experience economic loss due to worsening pavement conditions. The two analyses combined indicate that while some areas will experience greater impacts than others, that transportation funding shortfalls will negatively impact all areas in the state.

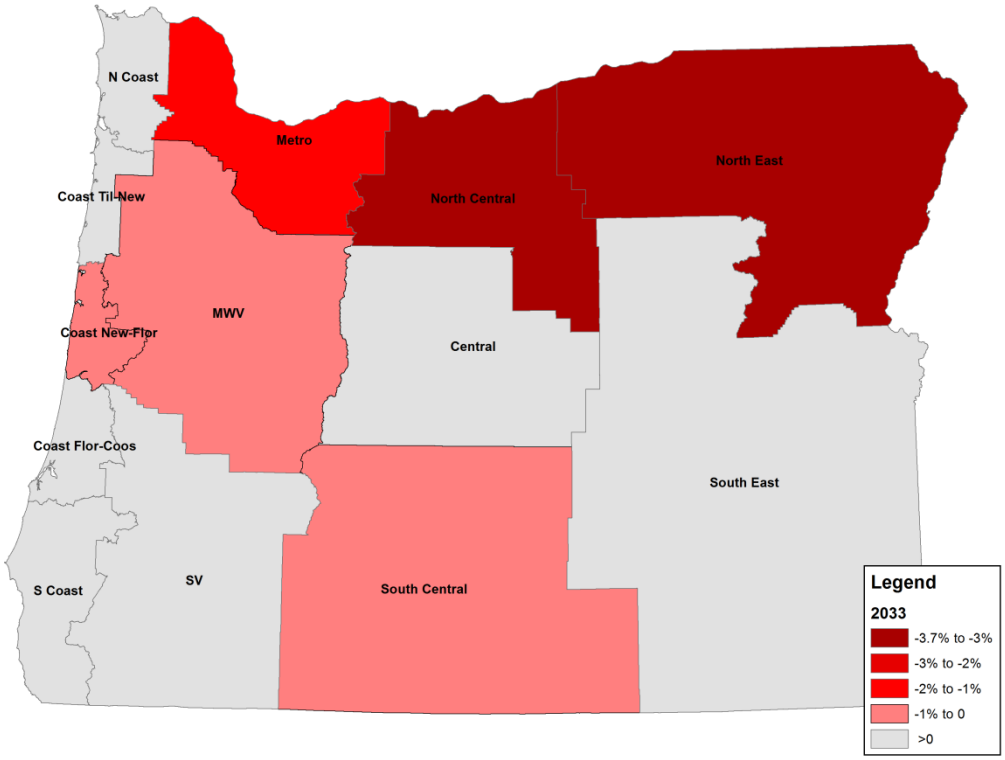



**Figure C3 Difference between Reference and District Highway Scenario Forecast Change in Employment 2035**