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GOOD ROADS COST LESS
2006 Study Update

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Utah Department of Transportation Research and Development Division

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16. Abstract

In October of 1977, The Utah Department of Transportation (UDOT) published the results of a research study entitled “Good Roads Cost Less: Pavement Rehabilitation Needs, Benefits and Costs in Utah.” The Good Roads Cost Less study was revolutionary when published and it is still referred to today as an excellent study to explain the need for maintaining pavements and infrastructure assets in good condition.

Almost thirty years later UDOT continues to face challenges maintaining pavements in good condition within the context of a constrained budget environment. This report presents an update to the original Good Roads Cost Less study and takes into account additional factors and data that were unavailable when the first study was undertaken. The report reaffirms that Good Roads do indeed Cost Less for the State of Utah and anyone traveling along the UDOT Highway network.

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1. Executive Summary

This report presents an update to the original Good Roads Cost Less study undertaken in 1977. The report reaffirms that Good Roads do indeed Cost Less for the State of Utah and anyone traveling along the UDOT Highway network.

The Good Roads Cost Less study was revolutionary when published and it is still referred to today as an excellent study to explain the need for maintaining pavements and infrastructure assets in good condition.

This report updates the original study and includes new performance measures and analysis methodologies that were not available when the original study was published.

1.1 Transportation within Utah

In the years since the original study was published, population growth and transportation demand have stretched and strained the transportation network to the fullest. During this same time period, the nation's infrastructure capacity has not kept up with the increase in demand for transportation. Along with the increase in travel demand and the lack of adequate new facilities to accommodate the increased demand, the infrastructure across the nation is aging and requires increased levels of preservation and rehabilitation expenditures to maintain the network in an acceptable condition.

Travel demand expressed in vehicle miles traveled across the United States during the years from 1980 to 2001 increased over 82% as follows[1]:

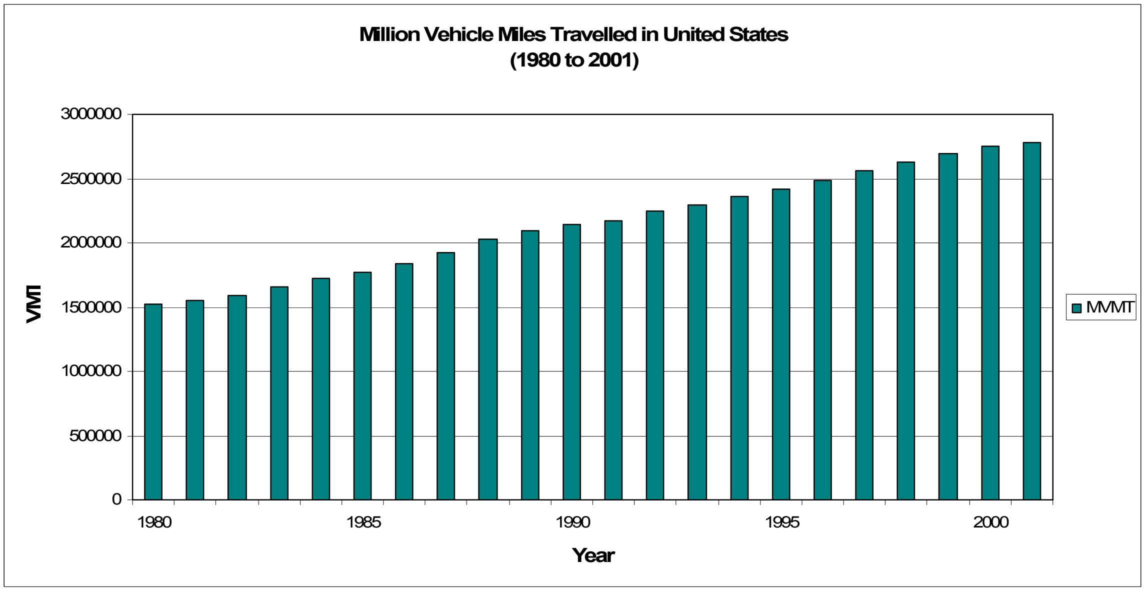


Figure 1: United States Travel Demand 1980 - 2001

When the historical state highway system is investigated over the last decade, the growth in the total state network mileage has only seen an increase of approximately 53 (center line) miles while the traffic traveling over those roadways has increased tremendously. In simple terms, the use of the state highway network has increased significantly but the size of the network has remained virtually the same.

The total roadway transportation network in Utah is comprised of the following roadway systems and associated vehicle miles traveled (VMT)[2]. VMT is calculated by multiplying the length of the network by the total amount of vehicles using that network in one year.

Roadway Classification	Total Mileage	Annual VMT	% of Total VMT
State Highway System	**5,846**	**17,080,351,939**	**69.31%**
County Road System	23,637	2,056,303,078	8.34%
City Street Network	9,215	5,421,705,255	22.00%
Forest Service Roads	2,327	83,297,819	0.34%
National Park Service	685		
Native American	723		
Other Federal Agencies	271		
Total	**42,704**	**24,641,658,091**	**100%**

Table 1: Annual Vehicle Miles Traveled (2004)

Approximately one third (8.9 billion) of the annual VMT (24.6 billion) takes place on the Interstate system with approximately two thirds of that VMT taking place on urban interstates and one third of that VMT taking place on rural interstates. The annual VMT figures displayed in Table 6 underscores the crucial importance of the Utah highway network and the need to maintain the facilities in an operable condition.

1.2 The Challenge to UDOT

UDOT must find an effective funding balance between system expansion to handle the increased demand and the need to maintain the existing network in good condition. In order to achieve the understanding necessary to begin to balance the funding between expansion and preservation, it was first necessary to determine the effects of different preservation and rehabilitation strategies on the Utah highway network. That need led to this update of the Good Roads Cost Less Study.

1.3 The Good Roads Cost Less Study Update

UDOT has established systematic processes for maintaining the different state highway network classifications at various levels of performance. The authors of this study determined the impacts of different performance targets on the network and the users of the highway network.

Deighton and UDOT configured UDOT's dTIMS CT Pavement Management System (PMS) to analyze many different alternative strategies for maintaining and rehabilitating the UDOT highway network over a 20 year analysis period. The goal of the study was to determine the effects of different policies on the study analysis variables and to determine target condition levels for maintaining the UDOT pavement network.

1.4 The Good Roads Cost Less Study Analysis Variables

This study investigated the performance targets for the various highway functional classifications within Utah and validated their effectiveness in terms of pavement condition and other significant factors as outlined below:

Agency Costs: Maintaining the state highway network at any performance target has a cost associated with it. This part of the study determined the various costs associated with maintaining the network at various condition levels.

User Costs: The users of the highway network incur an annual cost for traveling the network in terms of fuel costs, wear and tear on the vehicle and wear and tear on the tires. The cost to the user increases depending on the condition of the roadway. The study investigated user costs within Utah and developed a relationship between pavement condition and performance targets and the user costs incurred by the traveling public.

Safety: Maintaining the highway network in good condition contributes to lower accident rates across the state. The study investigated accident rates related to pavement condition to develop a relationship between the two and how safety impacts the performance targets.

Delay Costs: Delay costs may seem slight when one individual vehicle is examined but when the delay of all vehicles are taken into consideration the delay costs to the traveling public are quite substantial. When UDOT performs preservation and rehabilitation projects on the highway network, delay costs are introduced to the traveling public through detours and congestion. These delay costs have an impact on the timing of preservation and rehabilitation projects as well as system expansion projects.

By examining these relationships and including them in the decision making processes within UDOT, UDOT has a greater understanding of the effects of funding allocation decisions between preservation and system expansion on the performance of the state highway system.

1.5 The Good Roads Cost Less Study Analysis

The alternative strategies investigated by UDOT and Deighton are described in the following table and then a brief description of the scenario follows.

Strategy Number	Strategy Name
01	Do Nothing
02	Maintenance Only
03	Reconstruction Only
04	Current Model - No Budget Categories
04	Current Model – With Budget Categories

05	Cycle 6 Years and 10 Years - No Budget Categories
05	Cycle 6 Years and 10 Years – With Budget Categories
06	Cycle 6 Years and 12 Years - No Budget Categories
06	Cycle 6 Years and 12 Years – With Budget Categories
07	Cycle 8 Years and 10 Years - No Budget Categories
07	Cycle 8 Years and 10 Years – With Budget Categories
08	Cycle 8 Years and 12 Years - No Budget Categories
08	Cycle 8 Years and 12 Years – With Budget Categories
09	Cycle 10 Years and 10 Years - No Budget Categories
09	Cycle 10 Years and 10 Years – With Budget Categories
10	Condition 10% Less - No Budget Categories
10	Condition 10% Less – With Budget Categories
11	Condition 20% Less - No Budget Categories
11	Condition 20% Less – With Budget Categories
12	No Funding Five Years - No Budget Categories
12	No Funding Five Years – With Budget Categories
13	50% Funding Five Years - No Budget Categories
13	50% Funding Five Years – With Budget Categories

Table 2: Alternative Strategies

Within the dTIMS CT Pavement Management System, the optimization functionality allows the users to choose if they want the optimization to spend the available funding according to the established Budget Categories or without regard to the Budget Categories. In Table 35, the "With Budget Categories" and "No Budget Categories" designation indicates if the Budget Categories were used or not.

If No Budget Categories (NBC) were used within the strategy, dTIMS CT could spend the annual budget without respect to any categories or pots of money. If mathematically optimal, dTIMS CT could spend 100% of the funding on rehabilitation treatments (Blue Book Projects) or 100% of the funding on minor maintenance and preservation treatments (Orange Book Projects). When the strategy was implement With Budget Categories (WBC), the optimization was restricted to using dedicated Blue Book and Orange Book funding amounts without the ability to switch funds between the different budget categories.

The results for the analysis runs were completed and reported using a budget amount of $180 million per year increasing at 3% per year. The total amount of available funding for the $180 million dollar analysis is outlined in the following table:

Alternative Strategy Total Available Budgets	**Total**	**Blue Book Program**	Orange Book Program
No Categories Budget Amount	$4,836,667,408	n/a	**n/a**
Categories Budget Amount	**$4,836,667,408**	**$3,224,444,939**	**$1,612,222,469**

Table 3: Budget Distributions for $180 million scenario

1.5.1 Strategy 01 – Do Nothing

The Do-Nothing strategy was included to demonstrate the deterioration of the highway network and how quickly the highway network pavements deteriorate over time and how quickly the condition of the pavements deteriorates to poor condition. The Do Nothing strategy, though unrealistic for UDOT, demonstrates the tremendous increase in user costs and accident costs when the roughness (RIDE) and friction (SKID) deteriorate.

1.5.2 Strategy 02 – Maintenance Only

The Maintenance Only strategy was included within the analysis to demonstrate the affects on the network if all rehabilitation treatments were removed from the analysis and the routine maintenance program was responsible for maintaining the network in its current condition.

1.5.3 Strategy 03 – Reconstruction Only

The Reconstruction Only strategy was included within the analysis to demonstrate the affects on the network if UDOT adopted a "worst fist" type of programming. Worst First allows the highway network to deteriorate and incorporates reconstruction as the only alternative when the pavements get to poor condition.

1.5.4 Strategy 04 – UDOT Current Model

Strategy 04 represents the current UDOT dTIMS CT Pavement Management System with no changes and serves as the base model. Within the UDOT current model, asphalt treatments have an 8 year treatment timing cycle for both maintenance and rehabilitation type treatments and concrete has a 15 year cycle for any treatment. What this means within the analysis is that a segment receiving an initial treatment will not generate a subsequent treatment for at least 8 years for asphalt pavements and 15 years for concrete pavements.

1.5.5 Strategy 05 – Cycle 6 Years and 10 Years

Strategy 05 modified the UDOT base model and changed the treatment timing cycle to be 6 years for any maintenance treatments and 10 years for any rehabilitation treatments.

1.5.6 Strategy 06 – Cycle 6 Years and 12 Years

Strategy 06 modified the UDOT base model and changed the treatment timing cycle to be 6 years for any maintenance treatments and 12 years for any rehabilitation treatments.

1.5.7 Strategy 07 – Cycle 8 Years and 10 Years

Strategy 07 modified the UDOT base model and changed the treatment timing cycle to be 8 years for any maintenance treatments and 10 years for any rehabilitation treatments.

1.5.8 Strategy 08 – Cycle 8 Years and 12 Years

Strategy 08 modified the UDOT base model and changed the treatment timing cycle to be 8 years for any maintenance treatments and 12 years for any rehabilitation treatments.

1.5.9 Strategy 09 – Cycle 10 Years and 10 Years

Strategy 09 modified the UDOT base model and changed the treatment timing cycle to be 10 years for any maintenance treatments and 10 years for any rehabilitation treatments.

1.5.10 Strategy 10 – Condition 10% Less

Strategy 10 modified the UDOT base model and decreased the condition of every road section within the road network by 10%. This strategy was included to demonstrate what would happen to funding needs if the network was not in as good of a condition as it is today.

1.5.11 Strategy 11 – Condition 20% Less

Strategy 11 modified the UDOT base model and decreased the condition of every road section within the network by 20%. This strategy was included to demonstrate what would happen to funding needs if the network was not in as good of a condition as it is today.

1.5.12 Strategy 12 – No Funding for 5 Years

Strategy 12 modified the UDOT base model and allowed for 0 funding for the first 5 years of the analysis. This strategy was included to demonstrate what would happen to funding needs if the pavement maintenance and rehabilitation funding was cut altogether to supplement other assets or capacity improvements.

1.5.13 Strategy 13 – 50% Funding for 5 Years

Strategy 13 modified the UDOT base model and allowed for 50% funding for the first 5 years of the analysis. This strategy was included to demonstrate what would happen to funding needs if the pavement maintenance and rehabilitation funding was cut to 50% of normal levels in order to supplement other assets or capacity improvements.

1.6 The Good Roads Cost Less Study Analysis Results

Deighton and UDOT Summarized the analysis results for each strategy using and used summary charts and graphics to examine the effects of the strategies on each performance measure.

1.6.1 Agency Costs – The Costs to UDOT to Maintain the Network

Within each alternative strategy analysis, each optimization set was given the same budget amounts either as a total figure (no budget categories) or split into two different budget categories (the Orange Book minor maintenance and preservation category and the Blue Book rehabilitation and reconstruction category). The total 20 year analysis budget available was as follows:

Strategy	Total Available	Blue Book	Blue Book
No Budget Categories	$4,836,667,408	n/a	n/a
With Budget Categories	$4,836,667,408	$3,224,444,939	$1,612,222,469

Table 4: Optimization Budget Amounts

Strategy 12 and Strategy 13 had reduced funding in the initial 5 years of the analysis so the total available budget for those two analyses was slightly less.

The total agency cost of each strategy is outlined in Figure 2 as follows:

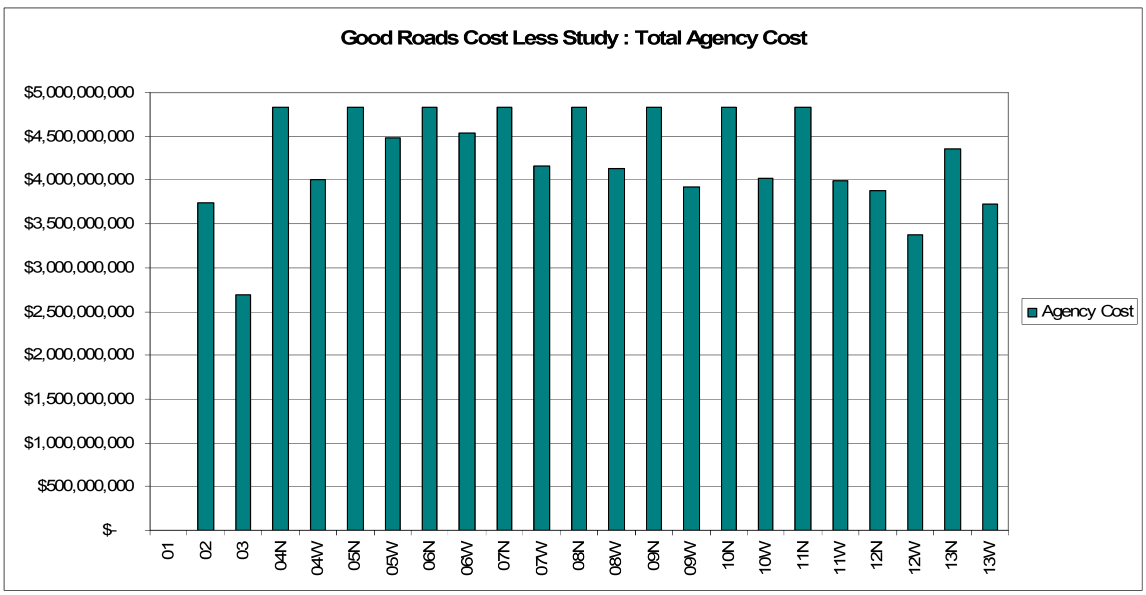


Figure 2: Total Agency Cost by Strategy

One thing that is evident immediately when looking at the Total Agency Costs is that the analysis consistently spent the entire budget amount in strategies where budget categories were not used. The strategies where the budget categories are used consistently do not spend the entire available budget and in some instances a surplus of $800 million goes unspent on the highway network. This surplus of funds is caused by timing of the maintenance and minor preservation treatments as well as the trigger mechanisms for these treatments which need to be investigated within the PMS model.

When the Agency Costs are presented in terms of Budget Categories, the source of the shortfall in expenditure becomes evident as shown in Figure 3.

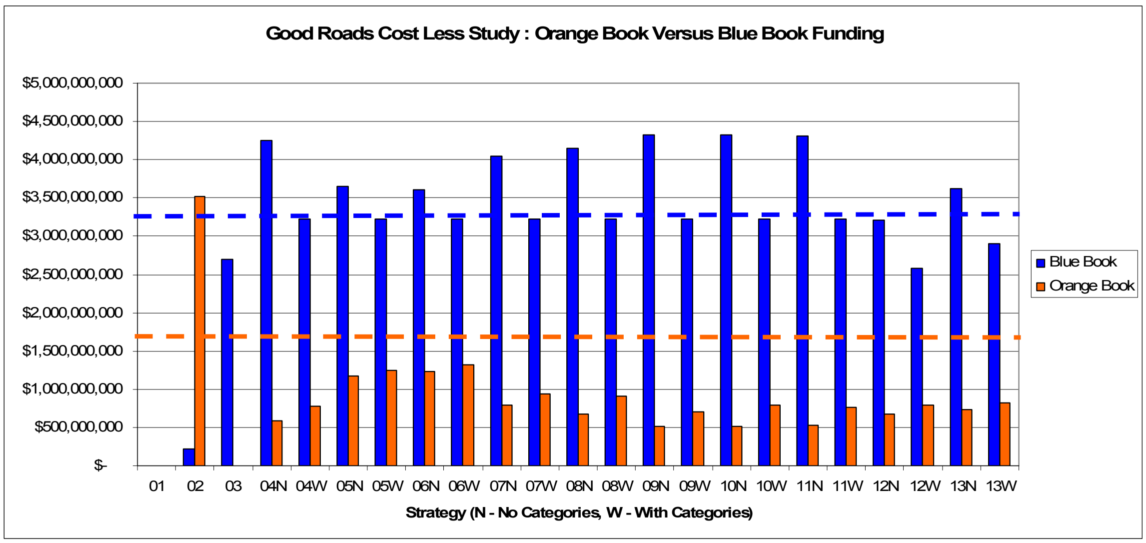


Figure 3: Orange Book versus Blue Book Funding

Orange book expenditures consistently fall below the available budget in the strategies where budget categories are used while the Blue book budget category consistently reaches full expenditure. When the maintenance cycle is shortened (Strategy 5 and Strategy 6) the Orange book expenditure is the greatest and a more thorough study of the timing cycle of Orange book treatments will be one of the recommendations of this study.

One of the explanations for the optimization selecting Blue book minor rehabilitation treatments over orange book seal treatments can be explained by looking at the costs and the benefits of each treatment. The Open Graded Seal Coat treatment costs slightly less than the Asphalt Minor Rehab treatment but the Asphalt Minor Rehab treatment gives significantly more benefit to the pavement. For the slight increase in cost, the benefits are higher so dTIMS CT prefers to select the Asphalt Minor Rehab over the Open Graded Seal Coat in many of the alternative strategies.

1.6.2 User Costs

The analysis has demonstrated that user costs within the network are increasing and will no doubt be a concern for motorists in the future. It is important to note here, that the user cost figures quoted in the report refer to the total user operating cost, not just the additional cost due to increased roughness. The User Costs range from a low of $229 billion to a high of $244 billion as shown in Figure 127.

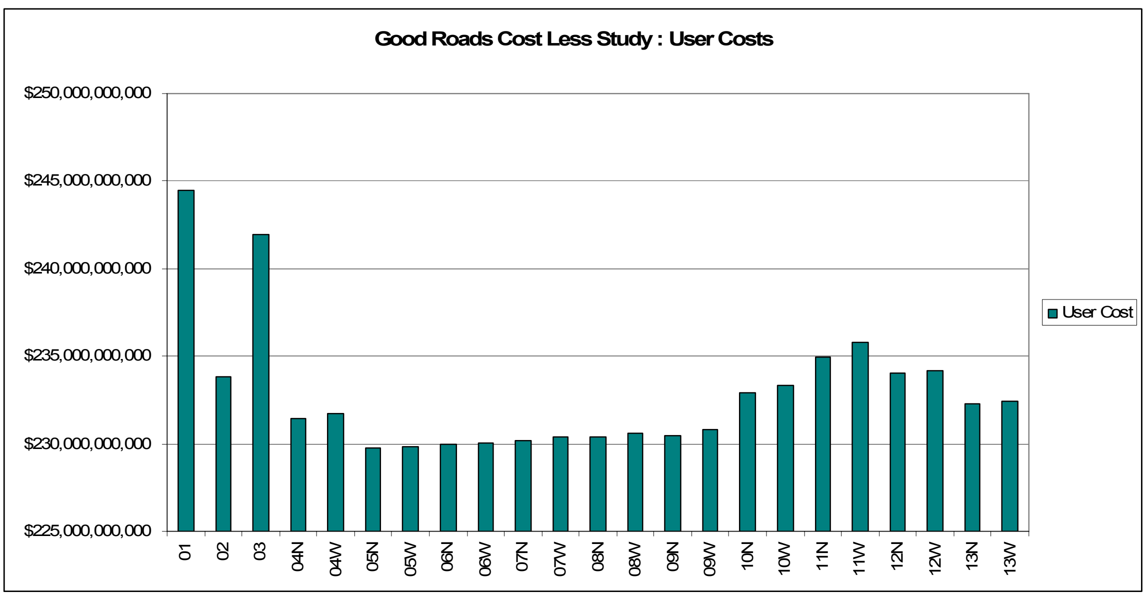


Figure 4: User Costs for By Strategy

It is important to note that the traffic level, percent trucks and user costs calculations are consistent within each of the strategies. The only variable that changed from strategy to strategy was the Ride Index which plays a role in the calculation of user costs.

What can be witnessed from the analysis results from Strategies 4 through 9 is that the user costs are relatively consistent around the $230 billion dollar level. This is related to the fact that the traffic is consistent through all of the strategies and each strategy keeps the Ride Index approximately the same throughout the analysis. The only large scale change in users costs come when the condition of the network deteriorates greatly (Strategies 1,2,3, 10N, 10W, 11N, 11W) and when the funding is reduced (Strategies 12N, 12W, 13N and 13W).

This evidence is further supported by the next figure which presents the user costs along with the Ride index variable in year 20 of the analysis.

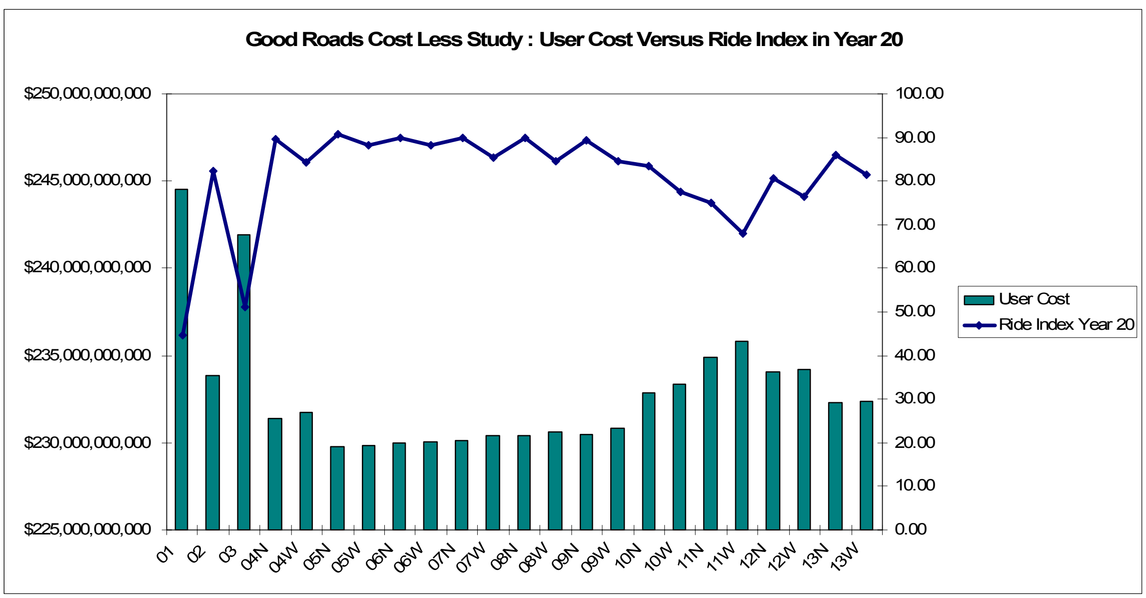


Figure 5: User Cost versus Ride Index

As far as user costs are concerned, a smooth ride helps reduce the total vehicle operating costs over the life of the analysis. But, a significant change in the Ride Index does not necessarily increase or decrease the user costs significantly.

When the Ride index is reduced by 10% the User Costs increase by less than 1% and when the Ride Index is reduced by 20%, the User Costs increase by only 1.5%. The overall user costs for the UDOT highway network are increasing dramatically for each scenario because the traffic levels across the highway network are increasing yearly. Within the analysis, an average annual growth rate of 5% was applied to the traffic volume for each pavement section, which causes the vehicle operating costs to increase significantly within each of the analyses completed for the study.

1.6.3 Accidents Costs

Much like User Costs and the Ride Index, Accident Costs within the analysis vary primarily based on the values of the Skid Number as the other variables are constant throughout each strategy.

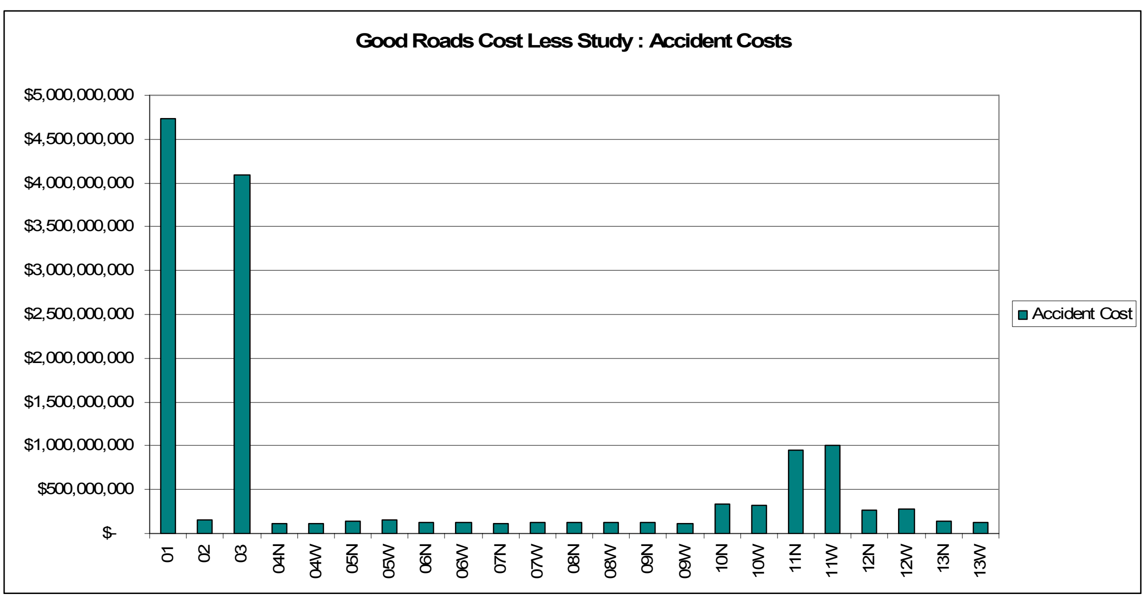


Figure 6: Accident Costs by Strategy

The increased Accident Costs based entirely on the Skid Number do not really play a factor in the analysis for strategies 4 through 9 (maximum of $159 million), but when funding is significantly reduced or the conditions of the network allowed to deteriorate into a fair and even a poor condition, the accident costs based on the deteriorating skid numbers increase quite quickly. The UDOT highway network is in good condition and in the case of accident costs, good roads do cost less.

These Accident costs are different and much lower than agency costs and user costs for the following reasons:

- Accident Costs are a "delta cost" which reflects only change in cost between increased accident rates due to low skid numbers and not the total cost of all accidents occurring on UDOT Highways;
- Not all safety related costs are included within the accident cost figures: costs due to roughness, rutting, potholes, edge drop offs and other factors are not included within the cost figures;
- Costs to society and to UDOT due to lawsuits between parties involved in the accident take funds away from other important department activities and are not taken into consideration.

1.6.4 Delay Costs

Delay costs give an indication as to which strategies impact the public the most through the delay caused by implementing the recommended maintenance and rehabilitation projects.

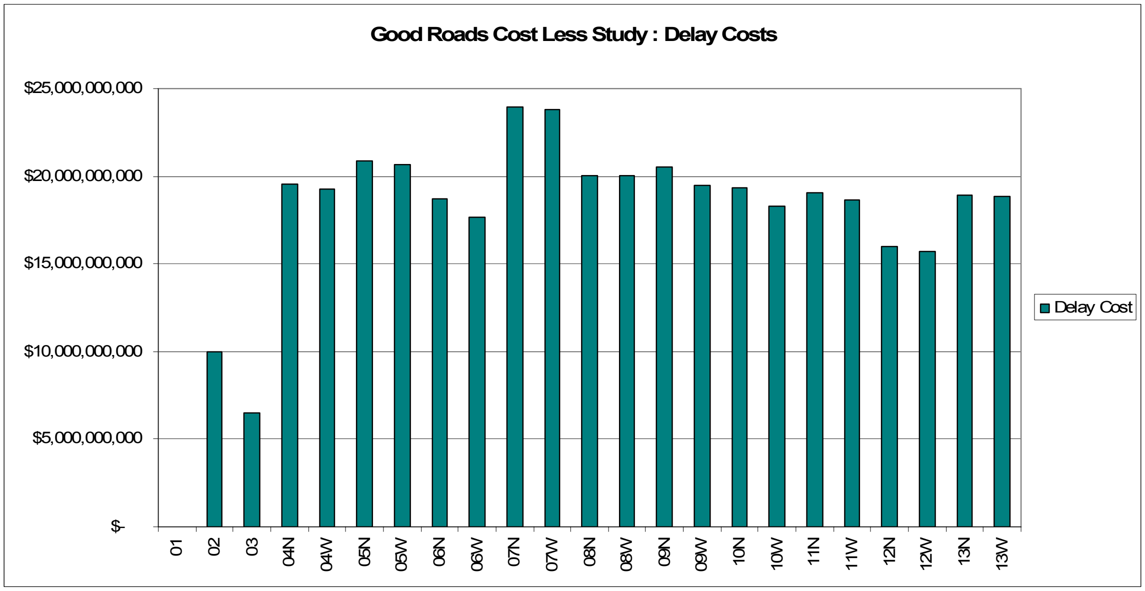


Figure 7: Delay Costs by Strategy

As can be seen in the results, the mix of minor maintenance and rehabilitation treatments has a slight impact on the Delay Costs as the minor treatments can be done without causing a great deal of delay. The strategies where the Blue book program expenditure far outweighs the Orange book program expenditure, the delay costs are slightly higher.

As you may remember from the individual strategy results, Strategy 7 sets the timing cycle to 8 years and 10 years and within this strategy approximately half of all the treatments completed within the analysis period are Minor Rehabilitation treatments which leads to an increase in delay costs which are higher than any other strategy. The miles of each treatment for each strategy are displayed in Table 84 as follows:

Strategy	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
01	0	0	0	0	0	0	0	0	0	0	0
02	1861	11990	677	0	0	0	311	193	0	0	15032
03	0	0	0	0	0	0	0	0	506	264	770
04N	3558	771	147	455	8276	638	358	79	119	121	14523
04W	3886	1474	193	235	6706	622	363	89	79	74	13721
05N	7636	1024	130	552	6002	723	733	532	143	115	17591
05W	7984	1149	130	380	5608	703	701	600	120	103	17479
06N	7583	949	89	833	5053	701	794	590	161	115	16867
06W	7879	1242	101	690	4690	679	731	657	134	103	16907
07N	3740	1132	138	467	7535	780	437	375	127	103	14834
07W	4370	1557	136	173	6432	808	429	375	96	93	14469
08N	3272	910	89	600	7248	790	426	223	156	115	13829
08W	3987	1588	101	220	5969	738	448	324	121	103	13599
09N	2026	1043	137	497	8053	851	274	56	141	103	13181
09W	2809	1559	159	135	6682	865	317	62	94	81	12762
10N	1617	1355	253	617	8658	558	177	48	52	90	13425
10W	1658	2523	273	382	6511	558	178	34	27	70	12213
11N	435	1928	329	1105	7169	361	93	31	33	108	11593
11W	393	3080	343	620	5669	361	97	6	17	82	10668
12N	1820	1871	280	343	6385	302	180	0	39	69	11289
12W	1978	2248	278	187	5299	304	178	0	20	69	10561
13N	3117	1721	205	308	7246	529	278	38	79	94	13615
13W	3459	1898	220	184	6024	553	311	22	55	69	12796

Table 5: Strategy Treatment Lengths (miles)

1.6.5 Overall System Condition

Figure 8 displays the resulting Overall Condition Index (OCI) in the last year of the analysis along with the total Agency Costs for each strategy.

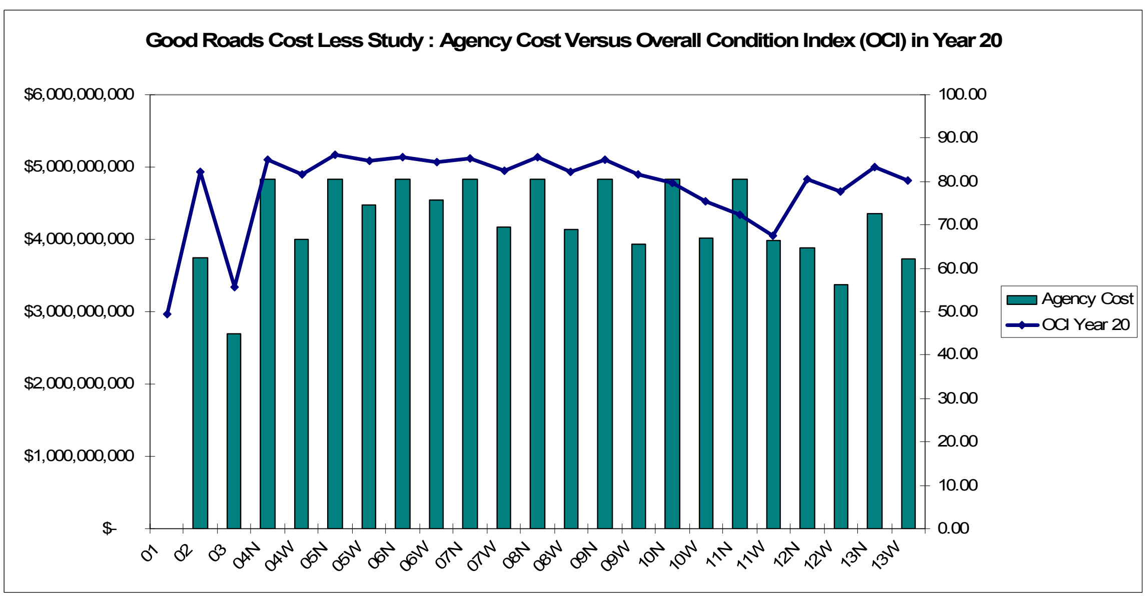


Figure 8: Agency Costs versus Overall Condition Index (OCI)

Strategies where UDOT maintains the current preservation and rehabilitation strategies, the overall network condition is maintained throughout the analysis period. In the strategies where funding is reduced, the network average condition deteriorates substantially which leads to a tremendous backlog of roads needing major rehabilitation improvements.

1.6.6 The Ride Index

Figure 9 displays the resulting Ride Index in the last year of the analysis along with the total Agency Costs for each strategy.

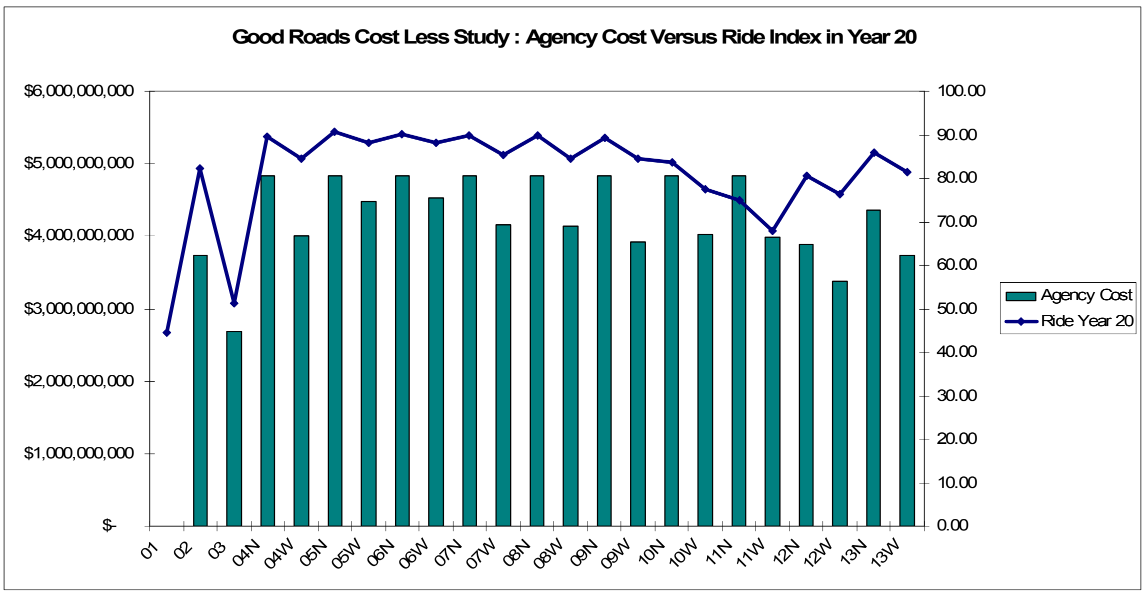


Figure 9: Agency Costs versus Ride Index

As was seen with the OCI, strategies where UDOT maintains current preservations and rehabilitation policy maintains the Ride Index at excellent level.

1.6.7 The Remaining Service Life Index

Figure 10 displays the resulting Remaining Service Life Index (RSL) in the last year of the analysis along with the total Agency Costs for each strategy.

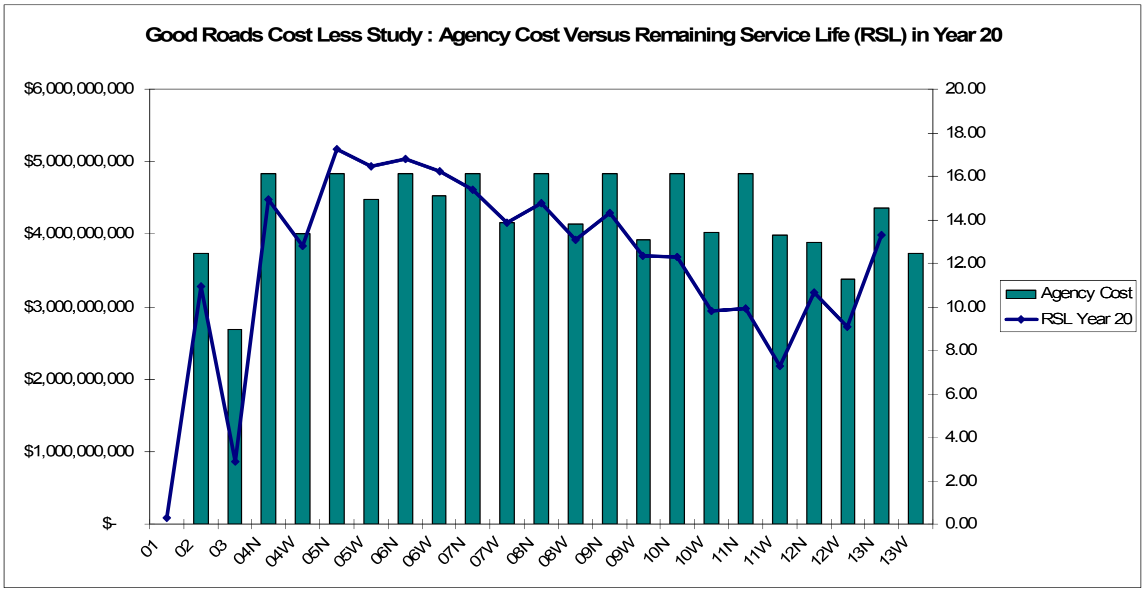


Figure 10: Agency Costs versus Remaining Service Life (RSL)

There is a noticeable difference in the RSL between the various strategies but those strategies that see UDOT maintaining current preservation and rehabilitation funding maintain the network RSL throughout the analysis period. Strategies where funding is significantly reduced creates a large backlog of pavement sections requiring major rehabilitation.

1.7 The Good Roads Cost Less Study Conclusions

Various strategies within the study show that a deterioration of the Utah highway network condition by amounts of 5%, 10%, and 20% would lead to an increase in user costs, accident costs and an increase in necessary funding to bring the system condition back current system condition levels.

Various strategies also indicate that current UDOT funding is adequate to maintain the highway system in its current condition but not sufficient to increase the system condition if any deterioration of more than 5% occurs.

This study has shown that a poor highway network impacts the economy and the citizens of Utah through increased accident costs, user costs, agency costs and delay costs as larger rehabilitation treatments are needed to restore the highway network to a good condition. Maintaining the network in good condition helps to reduce the impacts to the Citizens of Utah.

Good roads do indeed cost less and as stewards of the public infrastructure, UDOT must maintain the highway network in good condition to minimize the impacts on the citizens of the state.

If UDOT did maintain the condition of the highway network at a lower overall OCI with significantly less expenditure over the analysis period an increase in accident costs and user costs would occur and the overall structural health of the network would suffer.

The strategies in the study allowed the resulting average condition of the network to vary greatly from highs of 85 OCI to lows of 50 OCI with expenditures ranging from a high of $4.8 billion to a low of $2.6 billion for the reconstruction only strategy.

If UDOT were to allow the system to deteriorate to a value of 50 over the analysis period, the difference in costs between the two levels of condition would be approximately $2.2 billion which is only 13% of the $16.5 billion of the unmet highway needs outlined in the Utah Transportation 2030 Long Range Plan. After that 20 year period was completed, UDOT's rehabilitation needs would continue to grow substantially as the network deteriorated into poorer and poorer condition as witness in the looking forward table of costs, Table 85.

The recommendation of this updated Good Roads Cost Less study is similar to the recommendation of the Good Roads Cost Less study in 1977. UDOT must strive to maintain the highway pavement assets in as good a condition as possible to minimize the impacts of the network to the citizens of Utah.

The preservation and rehabilitation dollars that could be diverted away from the program to fund capacity improvements would not be significant to impact capacity throughout the UDOT network. But that diversion of funds would have a significant impact on the highway network condition and its maintenance and rehabilitation needs in the future and on the user costs, accident costs and delay costs for the citizens of Utah. Clearly, Good Roads Do Indeed Cost Less.

This conclusion and confirmation that Good Roads Cost Less is based upon the findings of the study and are summarized as follows:

- Pavements that are in good condition today can be maintained by an appropriate mix of minor maintenance, preservation and rehabilitation treatments that maximize the network OCI and prolong the life of the pavements.

- Pavements that are left to deteriorate to poor and very poor condition cause significant increases in accident costs, user costs, agency costs and delay costs.

- Pavements that are allowed to deteriorate to poor and very poor condition cannot be maintained through minor maintenance treatments as the treatment trigger mechanisms prevent inappropriate treatments taking place on pavements whose condition warrants a more extensive and expensive rehabilitation treatment.

- Pavements that deteriorate enough to bring the overall condition of the network lower by 20% or even by 10% can cause a funding crisis as the need for more expensive rehabilitation treatments raise the agency costs to the point where alternative funding solutions would be necessary.

- Current UDOT funding is sufficient to maintain the UDOT network in good condition but would be insufficient to restore the UDOT network to a good condition if the overall condition of the UDOT network were to deteriorate by as little as 10%.

- Diverting maintenance and rehabilitation dollars to support capacity enhancements (or other facilities or programs) will cause a deterioration of the road network overall condition throughout the analysis and would require a larger influx of money after the initial transfer of funds to restore the network to its current condition.

- When budget categories were used within the analysis, the resulting condition of the network was lower than the resulting condition when no budget categories were used even if no other parameters were changed. This leads to the recommendation that UDOT strive towards being more flexible in determining the funding for minor maintenance and rehabilitation treatments no matter the source of the funds.

Upon completion of this study, UDOT will investigate the performance goals for each of the systems (Interstate, Arterial, Collector and Network Wide) and present those goals to the Utah Transportation Commission for approval.

2. Introduction

In October of 1977, The Utah Department of Transportation (UDOT) published the results of a research study entitled "Good Roads Cost Less: Pavement Rehabilitation Needs, Benefits and Costs in Utah."[3]

The Good Roads Cost Less study stressed the need for maintaining UDOT pavements in good condition in order to minimize maintenance and rehabilitation costs to UDOT and user costs to the traveling public.

The study concluded that UDOT should strive to maintain its highway network pavements in a better overall condition than they were maintaining the pavement infrastructure at that time. This increase in overall condition would require additional funding to upgrade UDOT's poor pavements to good condition so that future maintenance, rehabilitation and user costs could be reduced. The study finally concluded that the increased funding could be recovered in as little as four years through improved benefits.

The Good Roads Cost Less study was revolutionary when published and it is still referred to today as an excellent study to explain the need for maintaining pavements and infrastructure assets in good condition.

Almost thirty years later UDOT continues to face challenges maintaining pavements in good condition within the context of a constrained budget environment. In order to help meet these challenges head on, UDOT Asset Management Director, Kim Schvaneveldt recognized the need to investigate current UDOT pavement management practices and spearheaded the development of the parameters for the study, the formulation of the research team and the funding necessary to accomplish the Updated Good Roads Cost Less study.

This report presents an update to the original Good Roads Cost Less study and takes into account additional factors and data that were unavailable when the first study was undertaken. The report reaffirms that Good Roads do indeed Cost Less for the State of Utah and anyone traveling along the UDOT Highway network.

2.1 *Changes in Transportation across the Nation*

In the years since the original study was published, population growth and transportation demand have stretched and strained the transportation network to the fullest.

Travel demand expressed in vehicle miles traveled across the United States during the years from 1980 to 2001 increased over 82% as follows[4]:

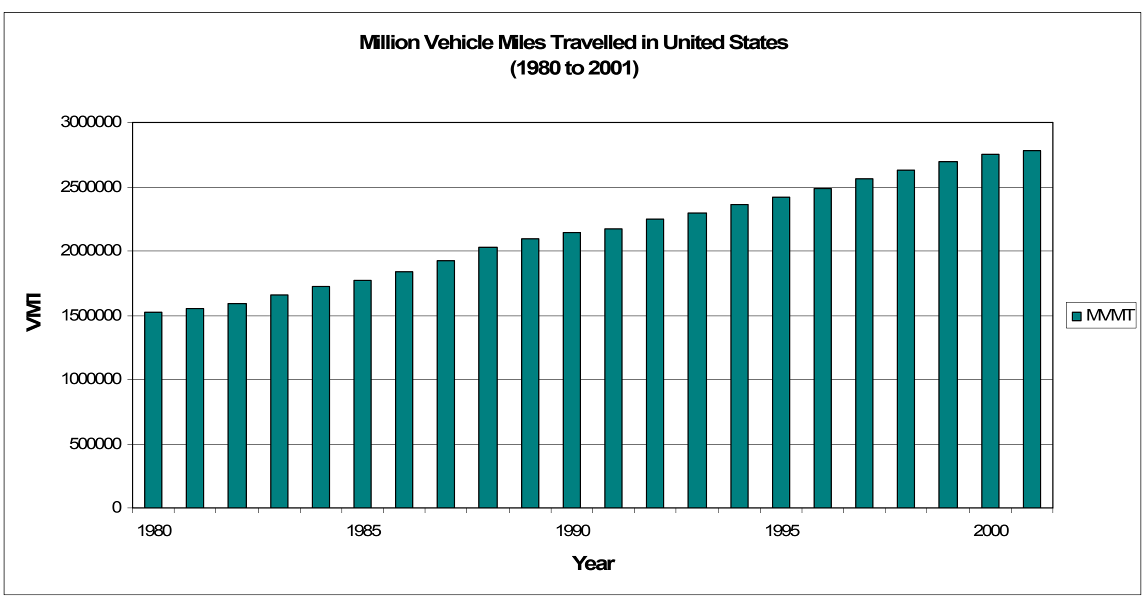


Figure 11: United States Travel Demand 1980 - 2001

During this same time period, the nation's infrastructure capacity has not kept up with the increase in demand for transportation. In fact, during the period from 1993 to 2001, the nation's infrastructure grew by only 11% and most of that growth was at the local (municipal and county) level and not at the state highway level[5]. The Federal Highways Association is predicting that by 2025 total vehicle miles traveled (VMT) will increase by nearly 50% and freight movements will double[6] but total lane miles will remain virtually the same.

This increase in travel demand has lead to alarming congestion which cost the American public over 3.7 billion hours of delay in 2003. These hours of delay translate into 2.3 billion gallons of wasted fuel and cost the public $63.1 billion.[7] Total user costs are significantly higher if the costs associated with lost productivity, air pollution, effects on driver and passenger physical and mental health and other important factors are quantified.

Along with the increase in travel demand and the lack of adequate new facilities to accommodate the increased demand, the infrastructure across the nation is aging and requires increased levels of preservation and rehabilitation expenditures to maintain the network in an acceptable condition. In the 1990s the condition of the nation's infrastructure remained virtually unchanged as displayed in Figure 12[8,9] although the investment in new infrastructure and infrastructure maintenance and rehabilitation has increased substantially.

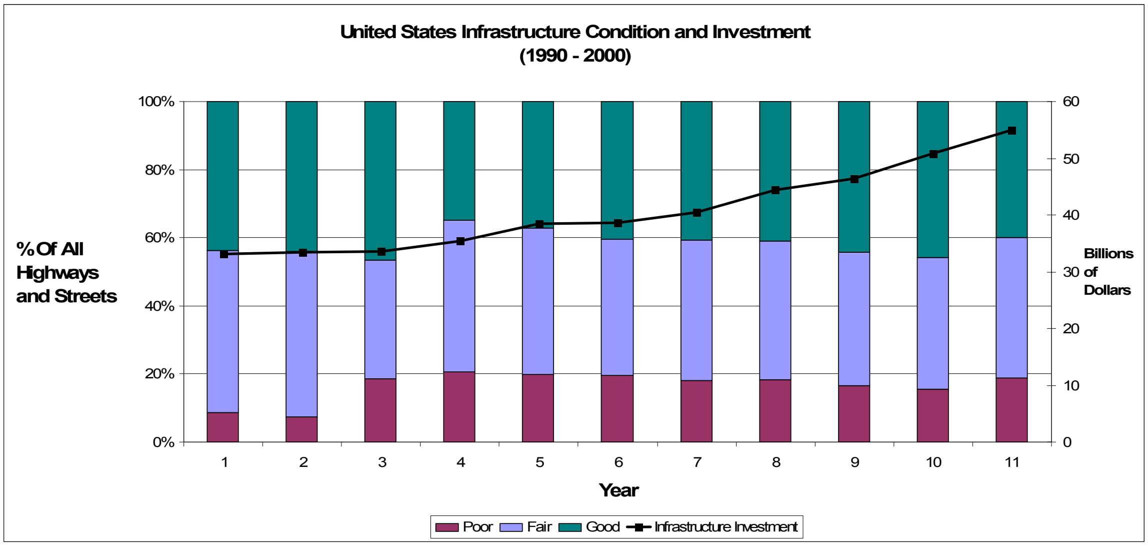


Figure 12: United States Infrastructure Condition 1990 - 2000

During this same time period, infrastructure investment across the United States on highways and streets has increased by $17.9 billion dollars. This investment has allowed transportation agencies to only maintain the existing condition of the network without any significant increase in the percent of good roads across the nation.

The facts and figures introduced so far point to the most significant challenge the nation faces in managing infrastructure across the United States. Travel demand has increased the need to build new facilities to increase capacity, invest heavily in public transit to reduce demand and to enhance existing facilities. At the same time the nation's rehabilitation and maintenance needs have stretched transportation investment dollars to the limit.

Transportation agencies across the United States are faced with this funding dilemma on an ongoing basis. Congestion mitigation needs, required to meet increased travel demand, compete with increasing preservation and maintenance funding needs required to preserve the network in its existing condition. Studies such as this update to the Good Roads Cost Less research completed by UDOT in the 1970s will help to determine effective preservation and rehabilitation strategies and goals for the public infrastructure which then in turn may free-up funding to help meet the demand for new capacity and public transit facilities.

2.2 *Changes in Transportation within Utah*

Since 1980, Utah's population has increased from 1.47 million people to over 2.19 million people in the year 2000 as illustrated in Figure 13.[10]

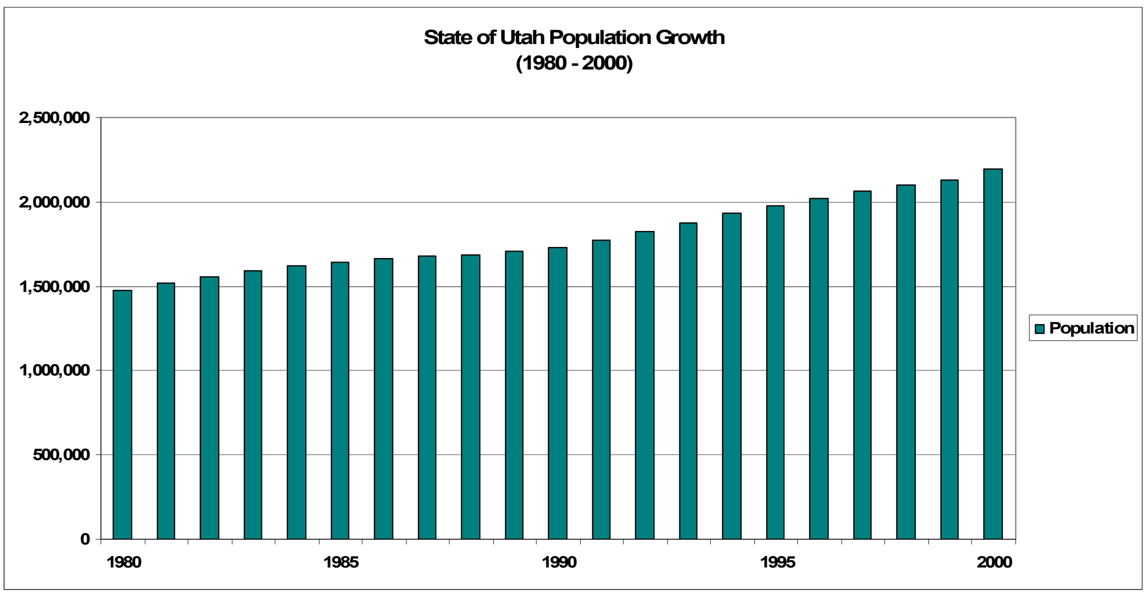


Figure 13: Utah Population Growth 1980 - 2000

Along with the increase in population, total vehicle miles traveled over the UDOT network has more than doubled as illustrated in Figure 14[11]:

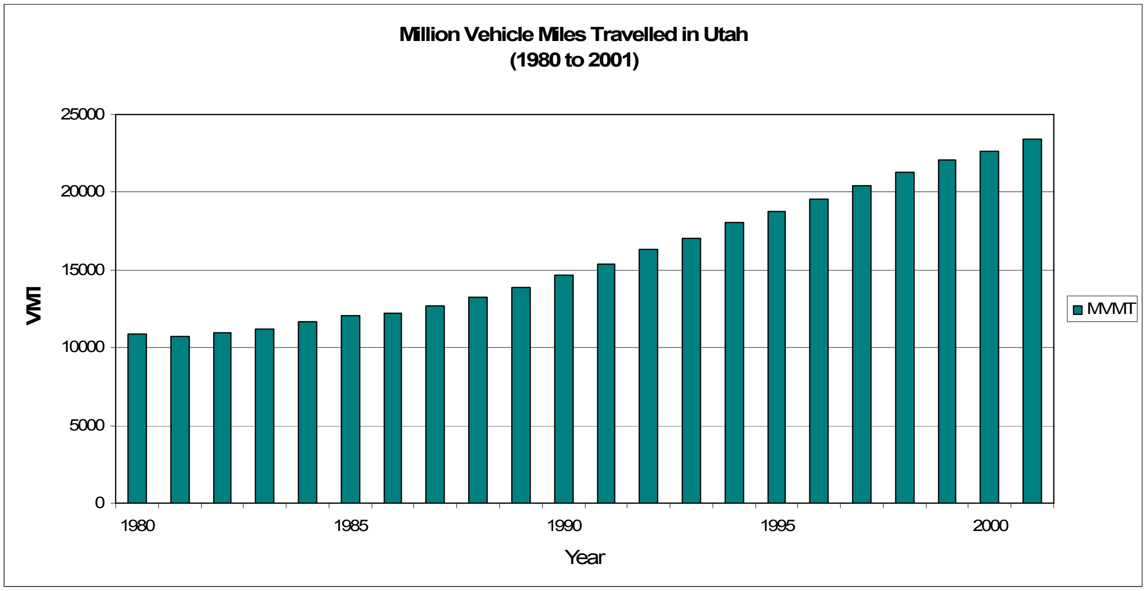


Figure 14: Million Vehicle Miles Traveled in Utah (1980 - 2001)

Not only are more miles being driven on UDOT highways annually, more and more licensed drivers are using them as well. During the period from 1990 through to 2001, the number of licensed drivers in Utah increased by 42%[12].

Forecasts indicate that Utah's population will grow from 2.5 million residents to 4.1 million residents by 2030, 4.7 million in 2040 and 5.4 million by 2050.[13] The population of citizens of driving age (16 and older) will increase from 1.9 million people to over 2.6 million people by 2030.[14]

The increase in population affects the transportation network at an ever increasing rate as demand for transportation and the amount of travel increases at a much faster rate than the growth of the population. This increase in demand for quality and effective transportation presents a significant challenge to UDOT whose mission is to provide, maintain and manage quality transportation facilities while minimizing the impact on the States resources.

2.3 Utah's Highway Transportation Network

The total roadway transportation network in Utah is comprised of the following roadway systems and associated vehicle miles traveled (VMT)[15]. VMT is calculated by multiplying the length of the network by the total amount of vehicles using that network in one year.

Roadway Classification	Total Mileage	Annual VMT	% of Total VMT
State Highway System	**5,846**	**17,080,351,939**	**69.31%**
County Road System	23,637	2,056,303,078	8.34%
City Street Network	9,215	5,421,705,255	22.00%
Forest Service Roads	2,327		
National Park Service	685		
Native American	723	83,297,819	0.34%
Other Federal Agencies	271		
Total	**42,704**	**24,641,658,091**	**100%**

Table 6: Annual Vehicle Miles Traveled (2004)

Approximately one third (8.9 billion) of the annual VMT (24.6 billion) takes place on the Interstate system with approximately two thirds of that VMT taking place on urban interstates and one third of that VMT taking place on rural interstates. The annual VMT figures displayed in Table 6 underscores the crucial importance of the Utah highway network and the need to maintain the facilities in an operable condition.

UDOT is responsible for providing and managing the Utah State Highway system which is the core of Utah's transportation system. Utah state maintained highways carry the greatest volume of people and freight of all the transportation modes within Utah. These highways provide mobility within different regions of the state and provide for statewide and interstate mobility. A historical breakdown of system mileage by urban and rural designation along with functional classification of the highways[16] is shown in Table 7.

State Highway Mileage Distribution by Urban / Rural Designation and Functional Class

Rural	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Interstate	768.7	770.9	770.9	770.9	770.9	770.9	770.9	770.87	771.00	770.00	724.20
Other Principal Arterial	996.5	996.4	996.4	996.5	996.5	996.4	996.4	996.42	996.00	996.00	959.40
Minor Arterial	1509.4	1512.3	1512.3	1500.3	1500.3	1500.3	1500.3	1500.32	1500.00	1500.00	1429.80
Major Collector	1664.7	1665.6	1665.6	1696.4	1697.8	1733.7	1730.0	1724.00	1730.00	1728.00	1596.60
Minor Collector	82.8	84.6	84.6	69.0	69.0	69.0	69.0	69.04	69.00	69.00	66.10
Local	20.5	20.3	21.7	21.7	21.7	21.7	21.7	21.68	22.00	21.00	18.30
Subtotal	**5042.6**	**5050.1**	**5051.5**	**5054.8**	**5056.2**	**5092.0**	**5088.3**	**5082.33**	**5088.00**	**5084.00**	**4794.40**

Small Urban	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Interstate	27.3	27.4	27.4	27.4	27.4	27.4	27.4	27.37	27.00	17.00	40.10
Freeway - Expressway	2.5	2.6	2.6	2.6	2.6	2.6	2.6	2.59	3.00	3.00	3.80
Other Principal Arterial	43.7	43.3	60.1	43.3	43.3	43.3	43.3	43.29	43.00	37.00	59.60
Minor Arterial	20.6	20.6	38.0	21.0	23.0	23.0	23.0	23.32	24.00	19.00	31.30
Collector	8.6	8.6	12.0	8.2	8.2	8.2	8.2	5.67	5.00	5.00	19.50
Local	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.80	1.00	1.00	3.00
Subtotal	**103.8**	**103.6**	**141.2**	**103.6**	**105.6**	**105.6**	**105.6**	**103.04**	**103.00**	**82.00**	**157.30**

Urbanized	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Interstate	141.4	141.7	141.7	141.7	141.7	139.8	139.8	139.76	142.00	153.00	175.60
Freeway - Expressway	5.8	5.9	5.9	5.9	5.9	5.9	5.9	5.86	5.00	5.00	14.20
Other Principal Arterial	204.2	208.6	192.1	209.4	214.1	220.5	220.5	219.44	222.00	229.00	234.90
Minor Arterial	249.0	248.3	230.9	246.3	246.5	246.5	246.5	244.42	242.00	247.00	304.50
Collector	37.7	37.8	34.5	38.0	38.0	38.0	38.0	38.02	37.00	39.00	151.00
Local	15.8	15.7	15.7	15.7	15.7	15.7	14.5	14.48	14.00	14.00	14.10
Subtotal	**653.9**	**658.1**	**620.8**	**657.1**	**661.9**	**666.4**	**665.2**	**661.98**	**662.00**	**687.00**	**894.30**

Total	**5800.3**	**5811.8**	**5813.5**	**5815.5**	**5823.7**	**5864.0**	**5859.1**	**5847.35**	**5853.00**	**5853.00**	**5846.00**

Table 7: Historical State Highway Mileage

When the historical state highway system mileage is investigated over the last decade, the growth in the total state network mileage has only seen an increase of approximately 53 (center line) miles while the traffic traveling over those roadways has increased tremendously. When the network is examined in terms of lane mileage, the total lane miles in 1994 were 14,897 and at the end of 2004 the total lane miles of highway network had increased by 296 lane miles to 15,193. In simple terms, the use of the state highway network has increased significantly but the size of the network has remained virtually the same.

The challenges of maintaining the existing highway network with the increases in travel demand are compounded by the variability and volatility in the construction cost index for UDOT. The construction index cost for pavement rehabilitation and structure rehabilitation have seen significant increases and decreases over the last decade with significantly large increases taking place in 2005.[17]

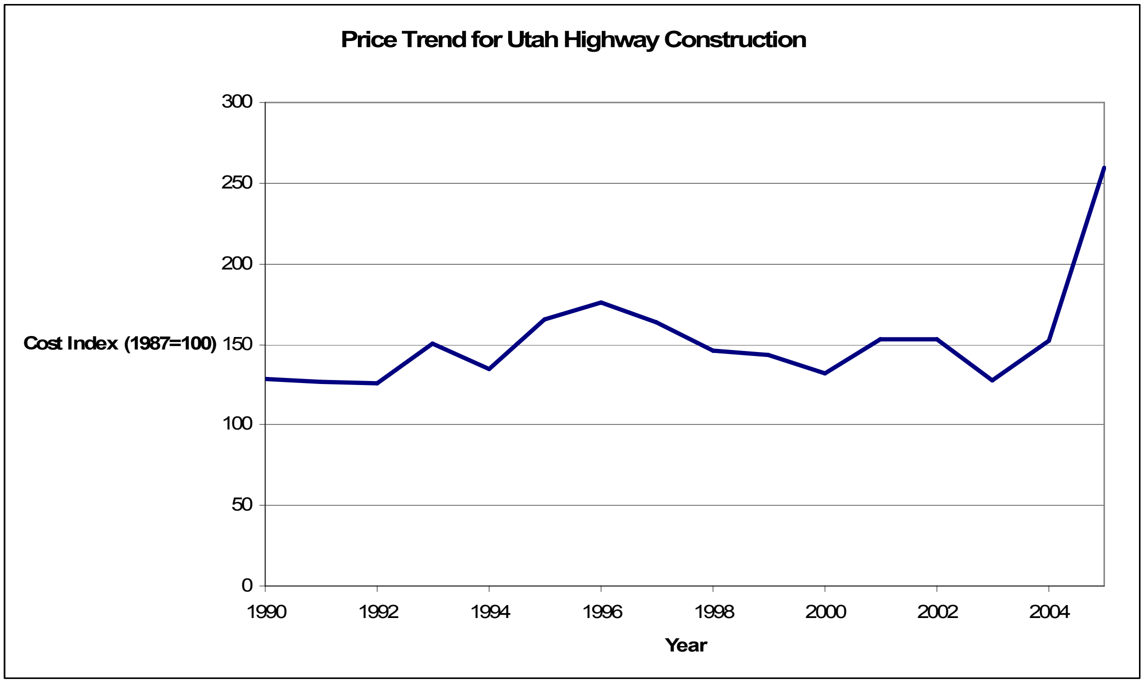


Figure 15: Price Trends for Utah Highway Construction

The construction cost index measures the relative increases and decreases in construction costs relative to the base year value of 100 from 1987. In the year 2005, the price of oil, cement, and other materials have increased significantly which accounts for the steep rise towards the end of the graph in Figure 15. It is unknown at this time if this is a short term fluctuation in pricing or more of a long term trend to higher material prices. At today's prices for reconstruction and replacement, the replacement cost of Utah's pavement assets would be over $12 billion dollars[18].

So far, the emerging picture for the highway network within UDOT is filled with the challenges of increased travel demand over an aging infrastructure that is increasingly more and more costly to maintain.

But within this environment the forecast is not all one of doom and gloom; UDOT's total highway revenue has been able to increase over the same period to help offset these challenges. Figure 16 displays a historical graph of the Highway User Receipts and Federal Funding within Utah from 1990 to 2005. During this period both the Highway User Receipts and the Federal Funding dollars have doubled. It is important to note here that the total of these two funding sources is not entirely directed to the state highway network but also distributed to cities, counties, aviation, public transit and other transportation agencies and users within the state. But overall, spending on the state highway network has increased.

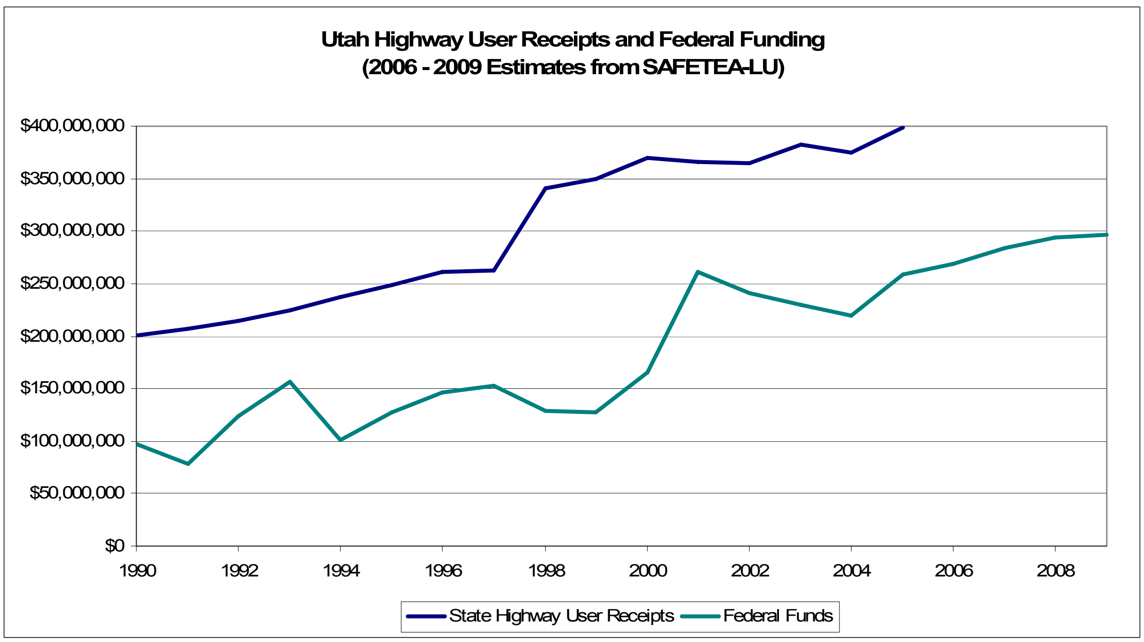


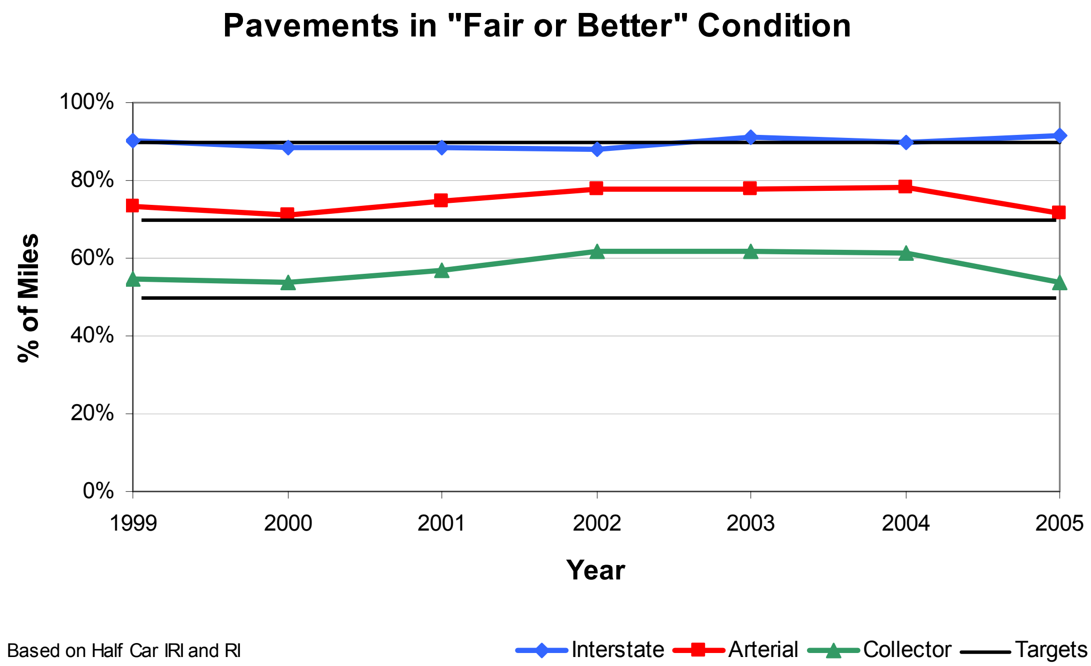
Figure 16: Transportation Funding in Utah (Federal, State, City and County)

In July of 2005 the US Government signed into law the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) which reauthorizes the Federal Funding for transportation agencies for the period ending in 2009. The fund authorizes approximately $286 billion dollars for transportation across the country with Utah's share approximately equal to

$1.4 billion over the legislation effective period. Of this $1.4 billion it is worth repeating that not all of these federal dollars go directly into the highway network but are shared across all modes of transportation within the state. It is not clear as of the writing of this report (Fourth Quarter 2006) how much funding from the SAFETEA-LU authorization will be available for preservation and rehabilitation of the Utah's pavement assets.

In conjunction with the increase in investment within the Utah highway network, during the 1980s and the 1990s UDOT has been maintaining the highway network using the principals established during the original Good Roads Cost Less study. Over the past several years, UDOT has managed to keep pace with the deterioration of the aging highway network and has maintained its pavement condition targets for the different classifications of highways within the State. These performance targets are specified in the percent of the network in fair or better condition. The resulting system performance of the pavements measured in terms of their roughness (how smooth a pavement is) is displayed in Figure 17.[19]

Figure 17: Historical Pavement Conditions



2.4 Goals and Objectives of the study

The initial discussion in the report describes the challenges facing UDOT as it maintains an aging state highway network which is under ever increasing demand.

UDOT must find an effective funding balance between system expansion to handle the increased demand and the need to maintain the existing network in good condition. In order to achieve the understanding necessary to begin to balance the funding between expansion and preservation, it is first necessary to determine the effects of different preservation and rehabilitation strategies on the Utah highway network and the users of the network.

UDOT has established systematic processes for maintaining the different state highway network classifications at various levels of performance. What this study will try to determine is the impacts of different performance targets on the network and the users of the highway network.

For example, the performance target specifies 90% fair or better condition on the Interstate which requires a level of preservation and rehabilitation to maintain this performance target. At the same time as the preservation and rehabilitation is taking place, delay costs are increasing due to capacity problems within the urban areas. It could be argued that the money invested to keep the Interstate system at 90% fair or better could be better invested to reduce congestion and user costs while experiencing only a slight drop in condition if it was maintained at 80% fair or better or further still at 70% fair or better. This study will look at the performance targets for the various highway functional classifications within Utah and validate their effectiveness in terms of pavement condition and other significant factors as outlined below:

Agency Costs: Maintaining the state highway network at any performance target has a cost associated with it. This part of the study will show the various costs associated with maintaining the network at various condition levels.

User Costs: The users of the highway network incur an annual cost for traveling the network in terms of fuel costs, wear and tear on the vehicle and wear and tear on the tires. The cost to the user increases depending on the condition of the roadway. The study will investigate user costs within Utah and develop a relationship between pavement condition and performance targets and the user costs incurred by the traveling public.

Safety: Maintaining the highway network in good condition contributes to lower accident rates across the state. The study will investigate accident rates related to pavement condition to develop a relationship between the two and how safety impacts the performance targets.

Delay Costs: Delay costs may seem slight when one individual vehicle is examined but when the delay of all vehicles are taken into consideration the delay costs to the traveling public are quite substantial. When UDOT performs preservation and rehabilitation projects on the highway network, delay costs are introduced to the traveling public through detours and congestion. These delay costs have an impact on the timing of preservation and rehabilitation projects as well as system expansion projects.

By examining these relationships and including them in the decision making processes within UDOT, UDOT will have a greater understanding of the effects of funding allocation decisions between preservation and system expansion on the performance of the state highway system.

In order to provide a thorough understanding of UDOT's decision making process the report will introduce the methodology that UDOT uses to manage the transportation network and the analysis tools that it has available in Section 2. Following that, Sections 3, 4 and 5 of the report will present the relationships and impacts of the main study areas, (agency costs, user costs, safety, and delay costs) on UDOT's maintenance and rehabilitation strategies for maintaining the transportation network.

Once the relationships were studied and determined, UDOT undertook an analysis of various alternative strategies within the pavement management systems to determine the effects of funding decisions on the primary areas of the study. This analysis methodology and the results are presented in Section 6.

Finally Section 7 presents the conclusions and recommendations of the study and presents items for future study and discussion.

2.4.1 Environment, Society and the Economy

In addition to maintaining a well performing highway network, UDOT is also ensuring compliance with the Clean Air Act Amendments of 1990. The Salt Lake, Ogden and Provo non-attainment areas have conformity requirements to assure vehicle emissions are within National and State established levels.

The Urbanized Area Metropolitan Planning Organizations, working with the Division of Air Quality, perform emission modeling to calculate the amount of vehicle emissions each year. The Wasatch Front Regional Council and the Mountainland Association of Governments each prepare a conformity determination for the Long Range Transportation Plans and the five-year Transportation Improvement Plans, that include all the UDOT highway projects in these areas.

Thru a combined effort of improved mass transit, improved vehicle efficiencies, and well selected highway projects UDOT is working to improve the air quality, as well as improve regional mobility.

During the study, UDOT investigated the inclusion of performance measures that quantified the performance impacts of the highway network on the environment, society and the economy.[20] [21] [22] [23] At present the models and performance measures investigated from worldwide asset management practices were found to be immature and inadequate and not suited for inclusion in the current study. UDOT realizes the highway network plays a crucial role for the enhancement and protection of the environment, society and the contribution to Utah’s economy and will include these factors within the asset management systems within UDOT when the models gain in sophistication and widespread adoption within the transportation community.

3. Managing UDOT's Transportation Infrastructure Assets

The value of UDOT's Transportation Infrastructure Assets throughout the state is significant and the replacement cost of those assets are increasing at a steady rate. In order to effectively manage the state highway transportation network throughout Utah, UDOT has implemented various policies, procedures, decision support analysis tools to ensure good stewardship of Utah's transportation assets. This section will introduce the management practices in place at UDOT starting with UDOT's policy on funding priorities within the network commonly referred to as UDOT's Final Four. UDOT's Final Four policy resulted from UDOT's realization that preservation of the existing highway network was crucial for the support of the transportation network and that any new capacity by way of system expansion would only take place once the maintenance and preservation of the existing system was guaranteed. Once the Final Four was adopted, UDOT continued to refine and enhance its management of the transportation network through new initiatives in asset management in conjunction with a renewed focus on short term and long term planning.

3.1 UDOT's Final Four

Recognizing that the decisions UDOT makes today will have substantial impacts on generations to come, the Utah Department of Transportation is driven in all it does by a set of strategic goals and focus areas. Known as the "Final Four," UDOT's strategic goals provide guidance in the department's efforts to improve the quality of life and economic vitality of the state. The final four department wide strategic goals are as follows:

1) Take Care of what we have.

UDOT maintains nearly 6,000 miles of roadways across the state, an investment worth billions of dollars. Increased travel is putting more and more pressure on the system, making preservation efforts even more critical. Indeed, the first goal could be re-stated as "Preserve our Highway System". In fact, UDOT has recently developed it's guidelines for new capacity projects, which states that money spent on system preservation must be adequate BEFORE we add more capacity; otherwise we put ourselves on a slippery slope from which we cannot recover. *This first goal gives the asset management system it's primary reason for existence*, which is to recommend budgets and preservation strategies for all assets on the transportation system. Although the investment represents "hard" assets such as pavements, bridges, guardrails, striping and signs, it is made more valuable by "soft" assets such as safety, mobility, and snow removal.

2) Make the system work better

. In the 21st Century, new technologies and design features will contribute as much to the efficiency of our transportation system as will new concrete and asphalt. The department is committed to implementing these features and staying on the leading edge of technology in order to optimize the existing system. Information is power, and the department strives to empower motorists to make wise travel decisions by delivering them the most accurate, up-to-date information about their routes. Proactively managing the transportation system, through travel demand management, access management, traffic signal coordination, ramp meters and incident management teams will help to optimize the system. High occupancy toll lanes, reversible lanes and carpool lanes are other system management techniques the department will explore in order to squeeze more capacity out of the existing system before adding additional lane mileage to increase capacity.

3) Improve safety

Safety is a major focus of the recent SAFETEA-LU Highway Reauthorization Bill and is the most important “soft”’ asset on Utah’s transportation system. By implementing innovative safety programs and identifying safety improvement locations, the department hopes to significantly reduce the number of traffic fatalities. Partnerships forged with law enforcement agencies and public education programs will also help to make Utah a safer place to live, travel, and conduct business. Safety is also improved by more than standard safety projects; indeed, all projects contribute to safety in some degree. In the planning stage, the asset management system uses the Safety Index as a factor in prioritizing projects. The same Safety Index is used by Traffic and Safety to help prioritize their improvements and is also used to prioritize capacity projects.

4) Increase capacity

During the past 16 years, Utah has added only 2% more capacity (in terms of lane miles) while vehicle miles traveled has increased at an alarming rate, so the need for additional capacity is becoming dire. Traffic congestion is often cited as a top concern amongst residents in Utah. To the traveling public, every minute spent delayed in traffic is a minute spent away from family, work or recreation. Given the state’s current increases in both travel and population, it is inevitable that either capacity will have to be added to the existing system or travel demand will have to be reduced. Financial constraints may prevent the department from building highways fast enough to completely eliminate congestion. With $16.5 billion in unmet highway needs through the year 2030[24], the department will explore tolling as a means of constructing projects on a much shorter timeline.

The adoption by of the Final Four goals by UDOT has allowed UDOT to focus on objectives for the transportation system that achieve the goals and has helped UDOT to recognize the need for good pavement and asset management practices to ensure a sustainable quality transportation system for now and the future.

3.2 Introduction to Asset Management at UDOT

During the past several years, UDOT has made great strides towards better asset management. Two teams have been assembled, involving senior leaders, managers and technical staff. The teams have taken surveys, created policies, and developed guiding documents that set forth the framework and implementation of asset management. Today, these teams continue to work through the various issues by improving policies, data, performance modeling and by performing the necessary asset management analysis.

3.2.1 Asset Management Operations

Asset management activities take place at three levels: strategic, tactical, and operational. At the strategic level, the Asset Management Team uses dTIMS CT[25] to perform asset group and cross-asset analysis in order to determine optimum funding levels to reach target conditions across the various assets. At the tactical level, Asset

Groups perform system level analysis in their respective management systems such as PONTIS, CARS, and dTIMS CT to generate recommendations for projects within the budget determined by the Asset Management System. At the operational level, the Regions assist the Asset Groups to refine the recommendations into a Long Range System Preservation Plan (SPP), which guides the Regions in selecting projects for the Statewide Transportation Improvement Plan (STIP). All three levels participate in sharing data, improving models, and developing the preservation projects.

Three documents are used for the planning and programming of preservation projects. They are the Long Range Transportation Plan (LRTP), the SPP, and the STIP. Although the LRTP is focused on the mobility issues, it also sets forth preservation processes, strategies and budgets. The SPP provides more detail by showing planning level details on preservation projects such as the project type, location, and cost estimate. It shows projects for all asset types (pavement, bridge, safety, mobility) together in one place, "harmonized" together so that they relate in location and time. Finally, the STIP gives detailed project-level information when projects are closer to construction.

3.2.2 Asset Management System

From the outset of the implementation[26], the Asset Management System (AMS) has not been considered as only a database and set of software tools but rather it has been designed as a sophisticated process involving people throughout the Department, clearly identified policies and procedures and established software tools that enable asset management to take place.

The AMS uses a life cycle cost approach to determine the treatment strategies for all assets that will enable UDOT to reach the optimum target condition levels. For pavement, bridges, and safety the conditions are overall condition index, bridge health index, and safety index, respectively. Up to this point, these targets have been fairly arbitrary, but with this study, those performance targets may be set with more confidence and incorporated more strongly within the AMS and the PMS.

The AMS software component is designed in a very open fashion so that it can be configured according to business practices at UDOT. It can be "asked" questions such as, "What is the optimum budget split between pavement, bridges, and maintenance features that will maximize performance of the highways system?" or "What will the conditions be for the next 20 years if pavement, bridges, and maintenance spend $180M, $60M, and $75M each?" The answers come in the form of charts, tables and graphs that are very useful for explaining UDOT's needs to the Utah Transportation Commission (UTC) and other decision makers. In fact, for the past two years, the Asset Management Director has used the results from the AMS analysis to give the UTC a needs analysis, which was well received. UDOT now has a repeatable, defendable, transparent system to generate highway needs based on policies, objectives, target conditions, data, models, and human knowledge.

3.2.3 Pavement Management at UDOT

Pavement Management at UDOT is an ongoing effort throughout most of the department. System level analysis is done in the Central Pavement Management group. Pavement condition data is collected each year and each pavement section is rated for performance. Using the dTIMS CT pavement management software, the measured conditions are used to generate and select the optimum treatment strategy that is required. The process can be used to identify the funding requirements for future years to maintain the system condition at the desired levels. With an approved funding level the model can then select the pavement sections and recommend the appropriate maintenance and rehabilitation treatments. The recommendations from the pavement management system from the Central Pavement Management group are then reviewed with the Regions and the Asset Management Group to develop the list of STIP projects.

3.2.4 The Pavement Management System (PMS)

Since 1993, UDOT has implemented the Deighton Associates Limited management system called dTIMS CT to manage the UDOT highway network.

During the pavement management analysis, the PMS produces a set of alternative treatment strategies consisting of one or more treatments applied during the pavement's life cycle for each section of pavement along the UDOT highway network. In order to develop these alternative strategies, dTIMS CT completes the following:

- Generates and manages performance measures from pavement input data for each section of highway to be analyzed;
- Forecasts condition (and other performance measures) into the future using performance models specific to various pavement families for each condition and performance measure used within the analysis;
- Investigates each possible treatment in each possible year of the analysis to determine if the treatment is applicable based on triggering rules and decision trees.
- For each treatment that is applicable, dTIMS CT applies the treatment, resets the performance measures affected by the treatment and then recalculates the future values of the measures as well as the costs of the treatment.
- Once the initial treatment is applied, dTIMS CT checks to see if another treatment can be applied in conjunction with the primary treatment before the end of the analysis. If so the treatment is applied, the performance

measures reset (as applicable) and the future values for each performance measure are calculated once again.

- This process is repeated multiple times for each pavement section so that a comprehensive list of strategies can be generated. An example set of strategies for a pavement section might look as follows:
    - Functional Repair in 2010 and Open Graded Seal in 2017 and Open Graded Seal 2026
    - Functional Repair in 2010 and Open Graded Seal in 2018
    - Functional Repair in 2010 and Functional Repair in 2020
- Once the strategies are generated, dTIMS CT calculates the costs and benefits of the strategies so that the most cost effective strategy can be selected depending on the budget available.

A sample treatment strategy is displayed in Figure 18. This strategy has one treatment in 2009 and a subsequent treatment in 2016. Strategies generated by the pavement management system can have as many as four treatments in a typical analysis period depending on the parameters used to configure the analysis and the length of the analysis period.

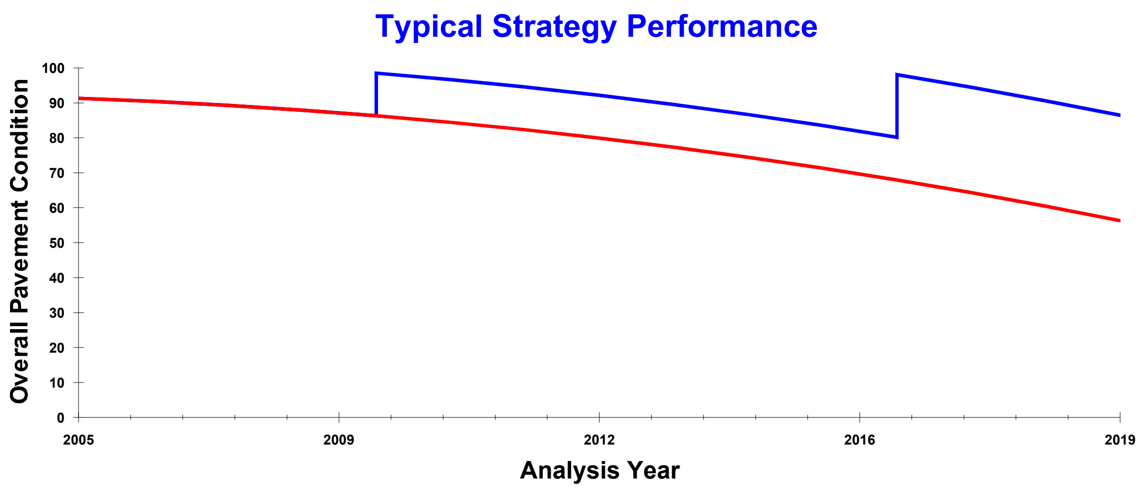


Figure 18: Example Treatment Strategy

In general, again depending on the configuration parameters, a typical analysis will produce between 50 and 150 different alternative treatment strategies for a pavement management section. The UDOT network has over 1,300 sections and the analysis generates approximately 188,000 alternative treatment strategies over the 20 year analysis period.

When the treatment strategies are graphed according to their costs and benefits, the graph will look like the following graph displayed in Figure 19.

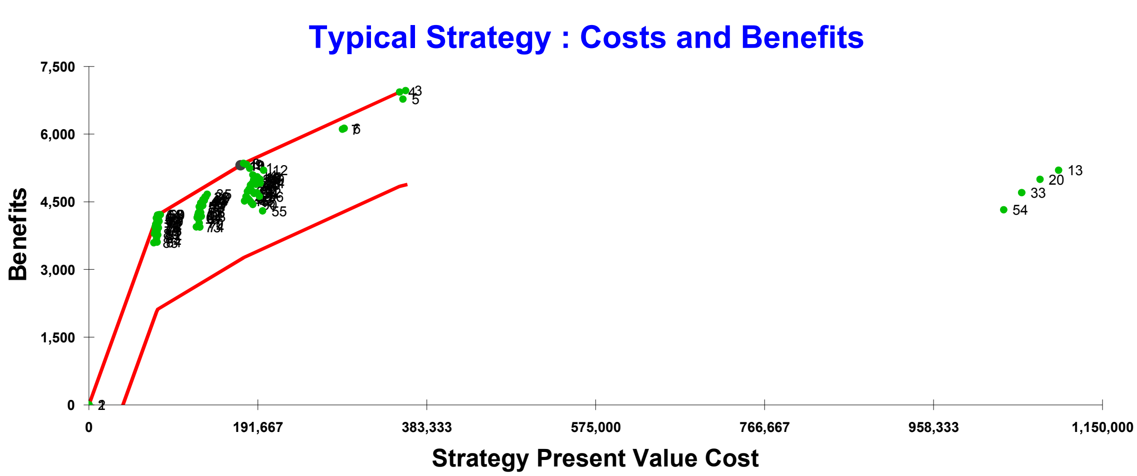


Figure 19: Typical Strategy Costs and Benefits

In Figure 19, each treatment strategy is plotted as a single dot according to the calculated net present value cost and benefits for the treatment strategy. The area in which the analysis will consider treatment strategies is called the efficiency zone and is defined by the two red lines. The PMS optimization decides which strategy is the best strategy for the segment depending on the funding dollars that are available and how those dollars are allocated between preservation and rehabilitation treatments and the objective function that the analysis supports.

On a network wide basis, the optimization starts at the highest benefit / least cost strategy and then moves within the efficiency zone to see if better and better strategies can be selected. This search continues until all of the available funding is used up and no more strategies can be selected for the funding that is available.

3.2.5 Enhancing the Pavement Management System Models

The pavement management models used within the PMS have been developed and enhanced throughout the lifetime of the PMS and underwent its last major revision in 2001. Prior to the commencement of the analysis for this Good Roads Cost Less study; the Central Pavement Management group at UDOT began another major series of enhancements to the pavement management model used within the PMS. Each of the various parameters used within the PMS underwent an intensive investigation to determine their accuracy and precision with respect to generating accurate and precise treatment strategy recommendations.

3.2.6 Pavement Families

When examining the entire state highway network to determine models for use within the PMS, developing individual models for each and every pavement section would be a very daunting task. So, in order to streamline the development of the models and lessen the total number of models that need to be developed and implemented within the PMS, the PMS uses the concept of pavement families to group similar pavements of similar characteristics and performance together.

UDOT has grouped pavements together into several pavement families based on pavement materials, speeds and traffic loadings which are outlined in Table 8.

Pavement Family	Length
Low Speed Concrete (< 40 mph)	7 miles
Medium Speed Concrete (> 40 and < 50 mph)	20 miles
High Speed Concrete (> 50 mph)	49 miles
Interstate Concrete	290 miles
Interstate Asphalt	645 miles
High Speed Asphalt (> 50 mph)	3,561 miles
Medium Speed Asphalt (> 40 and < 50 mph)	1,012 miles
Low Speed Asphalt (< 40 mph)	264 miles
Gravel	14 miles

Table 8: Pavement Families used within the PMS

3.2.7 Pavement Condition Data

Each year UDOT collects pavement condition data with UDOT personnel specifically trained to operate the testing equipment. The condition data can be classified into the following categories:

Profile Data: A high-speed profiler is used to measure the surface roughness, wheel path rut depth, and concrete joint faulting on a continuous basis for the entire network. In order to collect the profile data, one lane of each facility is tested annually and the results are considered to be representative of all lanes on that facility.

Skid Data: A locked-wheel skid trailer is used to measure the skid resistance of wet pavement. One skid test is completed within each mile of the network on a two year cycle.

Deflection: A falling weight deflectometer is used to measure pavement strength which includes surface deflections, pavement material modulus values and concrete slab load transfer efficiency. This test is completed once for every mile of pavement within the network on a mile by mile basis on a four year cycle. The PMS does not currently make use of the deflection testing but the results are used in pavement design once a project has been programmed.

Distress: Pavement cracking and distress data is collected manually by UDOT personnel on a yearly basis. A representative $1/10^{th}$ mile sample is taken for every mile of roadway and the values extrapolated to represent the entire mile. This information is used within the PMS.

The raw data collected by manual and automated means is converted to an index from 0 to 100, where 100 represents a perfectly new pavement. The index scale was set with boundary points at 90, 70, 50 & 30 to separate the pavement conditions into ranges of very good, good, fair, poor & very poor.

For each of the conditions being measured a maximum allowable threshold value was determined for when a major rehabilitation or reconstruction would be triggered, and set to the Index = 50 (or in Remaining Service Life (RSL) terms, RSL = 0). For example, if 120 transverse cracks in one mile of pavement were considered to be the threshold value where a major rehabilitation or reconstruction would take place, then 120 transverse cracks in one mile of pavement would represent an index value of 50. Any amount of transverse cracks over and above 120 would lower the index and any amount of transverse cracks below 120 would raise the index upwards until it became close to a newly constructed section and an index score of 100.

Table 9 outlines the performance measures that are calculated from the raw condition data.

Performance Measure	Technical Description	Layman's Description
Concrete Ride	Based on the average IRI from the Left and Right Wheel paths.	Ride is a measure of how smooth or bumpy the ride is while traveling normal highway speed.
Concrete Cracking	Based on % slabs with corner breaks and % slabs shattered	In any given section of jointed concrete pavement, how many slabs are completely broken or broken at the corners?
Concrete Faulting	Based on the number of joints experiencing faulting per mile.	Faulting is the vertical separation of slabs on jointed concrete pavement. It causes the "ka thump, ka thump, ka thump" sound when driving at highway speed over jointed concrete pavement.
Concrete Spalling	Based on number of spalled joints/mile.	Concrete joint spalling is the breakdown (cracking and crumbling) of the edges of the concrete at the joints.
Asphalt Ride	Based on the average IRI from the Left and Right Wheel paths.	Ride is a measure of how smooth or bumpy the ride is while traveling normal highway speed.
Asphalt Environmental Cracking	Based on surface distress caused by environmental factors and not necessarily load related.	Cracking caused by the freeze thaw cycle and not by loading on the pavement. Typically shows up as transverse cracks and block cracks.
Asphalt Wheel Path Cracking	Based on surface distress caused by traffic load and not environmental factors.	Cracking caused by heavy loads stressing the pavement structure and not by freeze thaw cycles.
Asphalt Rutting	Based on wheel path rutting caused by traffic loading.	Pavement deformation in the wheel paths caused by loads stressing the pavement structure.

Table 9: Performance Measures from Raw Condition Data

For each performance measure, there may be several different failure thresholds classified by the different pavement family. For example, rutting on the interstate will have a lower threshold value (in inches) than low speed and low volume asphalt pavements. The threshold values that define a failure are outlined in the following tables, Table 10 for concrete pavements and Table 11 for asphalt pavements.

Performance Measure	Pavement Family	Condition at which a Failure Point of 50 is reached.
Concrete Ride (RIDE)	Interstate Concrete	IRI value of 140
	High Speed Concrete	IRI value of 150
	Medium Speed Concrete	IRI value of 160
	Low Speed Concrete	IRI value of 170
Concrete Cracking (CONK)	All Families	Based on 20% of the corner break score and 80% of the shattered slab score. A pavement section with 0 cracks and 0 shatter slabs equals and index value of 100.
Corner Breaks	Interstate Concrete	5% low severity corner breaks,

		4% medium severity corner breaks or 2% high severity corner breaks.
	High Speed Concrete	5% low severity corner breaks, 4% medium severity corner breaks or 2% high severity corner breaks.
	Medium Speed Concrete	10% low severity corner breaks, 7% medium severity corner breaks or 4% high severity corner breaks.
	Low Speed Concrete	10% low severity corner breaks, 7% medium severity corner breaks or 4% high severity corner breaks.
Shattered Slabs	Interstate Concrete	2% shattered slabs in a pavement section.
	High Speed Concrete	2% shattered slabs in a pavement section.
	Medium Speed Concrete	4% shattered slabs in a pavement section.
	Low Speed Concrete	4% shattered slabs in a pavement section.
Concrete Faulting (FALT)	Interstate Concrete	>= 240 faults per mile >0.1" and < 0.3" or >= 80 faults per mile > 0.3" and < 0.5" or >= 20 faults per mile > 0.5"
	High Speed Concrete	>= 240 faults per mile >0.1" and < 0.3" or >= 80 faults per mile > 0.3" and < 0.5" or >= 20 faults per mile > 0.5"
	Medium Speed Concrete	>= 400 faults per mile >0.1" and < 0.3" or >= 120 faults per mile > 0.3" and < 0.5" or >= 30 faults per mile > 0.5"
	Low Speed Concrete	>= 400 faults per mile >0.1" and < 0.3" or >= 120 faults per mile > 0.3" and < 0.5" or >= 30 faults per mile > 0.5"
Concrete Spalling (JTSP)	Interstate Concrete	24% low severity spalling or 12% medium severity spalling or 4% high severity spalling
	High Speed Concrete	24% low severity spalling or 12% medium severity spalling or 4% high severity spalling
	High Speed Concrete	30% low severity spalling or 16% medium severity spalling or 6% high severity spalling
	Low Speed Concrete	30% low severity spalling or 16% medium severity spalling or 6% high severity spalling

Table 10: Concrete Pavement Performance Thresholds

Performance Measure	**Pavement Family**	**Condition at which a Failure Point of 50 is reached.**
Asphalt Ride (RIDE)	Interstate Asphalt	IRI value of 130
	High Speed Asphalt	IRI value of 140
	Medium Speed Asphalt	IRI value of 150
	Low Speed Asphalt	IRI value of 160

Performance Measure	**Pavement Family**	**Condition at which a Failure Point of 50 is reached.**
Environmental Cracking (CRCK)	All Families	Based on the combination of transverse cracking, block cracking and skin patching.
Wheel Path Cracking (WPCK)	Interstate Asphalt	600 feet low severity or 200 feet medium severity or 30 feet high severity
	High Speed Asphalt	650 feet low severity or 250 feet medium severity or 40 feet high severity
	Medium Speed Asphalt	700 feet low severity or 300 feet medium severity or 50 feet high severity
	Low Speed Asphalt	800 feet low severity or 400 feet medium severity or 80 feet high severity
Asphalt Rutting (RUT)	Interstate Asphalt	> 0.4 inch rut depth
	High Speed Asphalt	> 0.5 inch rut depth
	Medium Speed Asphalt	> 0.6 inch rut depth
	Low Speed Asphalt	> 0.75 inch rut depth

Table 11: Asphalt Pavement Performance Thresholds

Each of the noted performance thresholds is used within the PMS analysis to trigger maintenance and rehabilitation treatments on the network.

3.2.8 The PMS Deterioration Models

In order to predict the condition of the pavement into the future, the PMS uses deterioration models to forecast the value of any condition performance measure. In Utah, asphalt pavements are modeled to have an effective life of 30 years, except for the Ride index, which is modeled for 45 years. Concrete pavements are modeled to have an effective life of 40 years, except fpr the Ride index, which is modeled for 35 years. The deterioration curves within the PMS follow these design lives to so that failure is reached between 30 and 45 years depending on the pavement type and the performance index. Figure 20 displays the performance models for each of the four effective model lives.

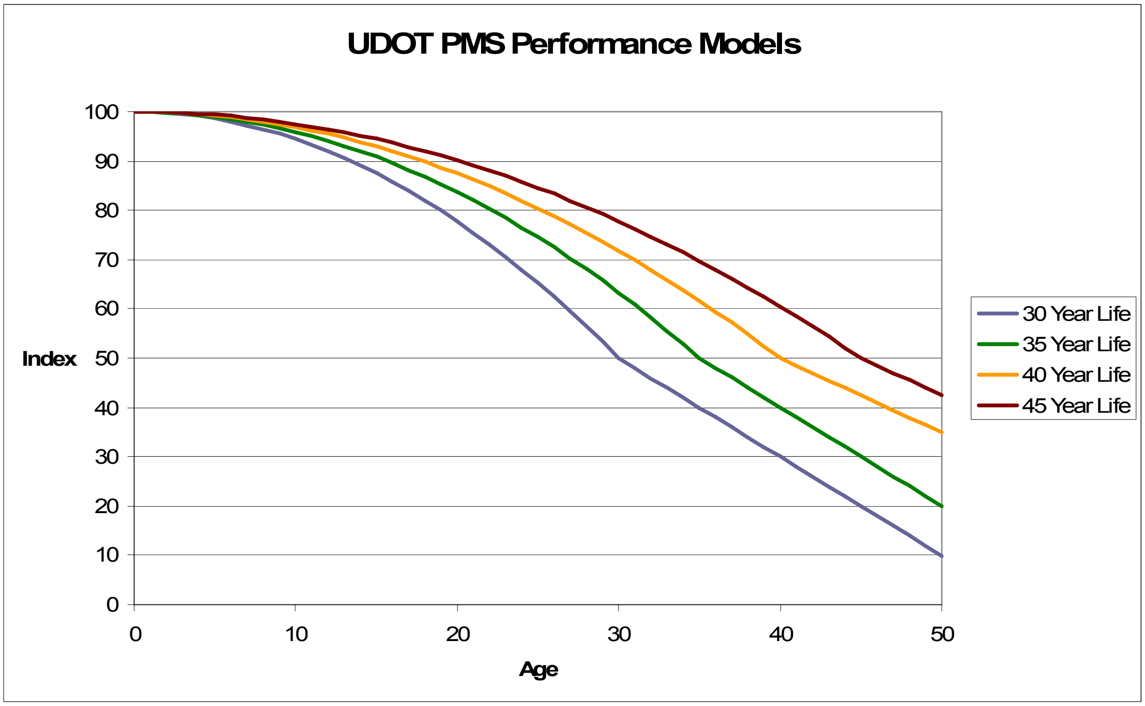


Figure 20: UDOT PMS Performance Models

3.2.9 The Overall Condition Index

The Overall Condition Index (OCI) is a composite index that is one of the indexes used to represent the overall health of the pavement section. It attempts to encompass each of the other distress indexes used within the PMS in a balanced format with no one index controlling the OCI.

For asphalt pavements, the OCI is calculated using the following expression:

(Ride Index + Cracking Index + Wheel path Cracking Index + Rutting Index)/ 4

For concrete pavements, the OCI is calculated using the following expression:

(Ride Index + Concrete Cracking Index + Faulting Index + Joint Spalling Index) / 4

The OCI is used as the objective function of the optimization to ensure a balanced approach to optimizing the overall pavement condition index and not one specific distress.

3.2.10 The PMS Preservation and Rehabilitation Treatments

The strategies generated by the PMS are made up of various preservation and rehabilitation treatments as follows:

Treatment	Example Projects
Preventive Maintenance Concrete	Joint sealing & spot grinding
Grind Concrete	Full section grinding
Minor Rehab Concrete	Partial or full depth slab replacement
Concrete Reconstruction	Full concrete reconstruction
Seal	Slurry Seal, Chip Seal, Nova Chip
Open Graded Seal	Open Graded Seal, SMA, Micro
Functional Repair	Seal with some rut fill, lane leveling and spot repair
Minor Rehab	Thin overlays, mill & replace up to 3"
Major Rehab	Mill and replace over 3", Structural overlays
Reconstruction	Full asphalt reconstruction

Table 12: Concrete and Asphalt Treatments

Treatments are selected based on the combination and level of forecasted conditions. The model looks at the current year condition index level and where it fits on a design life performance curve. The curve starts at an index of 100 and deteriorates over time to a value of 50 at year 30 for Asphalt & year 40 for Concrete. Different treatments are triggered at different Index levels.

The following trigger levels are used for each treatment being modeled:

Treatment	Trigger Mechanism
Preventive Maintenance Concrete	(RIDE and FALT) >= 70 and CONK >= 75 And (RIDE <= 90 or FALT <= 90 or JTSP <= 90)
Grind Concrete	(RIDE <= 60 or FALT <= 60) and CONK >= 60
Minor Rehab Concrete	(RIDE, FALT and CONK) >= 60 and (RIDE <= 80 or FALT <=80 or CONK <= 80 or JTSP <= 80)
Concrete Reconstruction	CONK <= 55 or FALT <= 55
Chip Seal	(RIDE, RUT and CRCK >= 70) and WPCK >= 75 And section preferred seal type is Chip Seal
Open Graded Seal	(RIDE, RUT and CRCK >= 70) and WPCK < 75 And section

	preferred seal type is Open Graded Seal
Functional Overlay	(RIDE, RUT or CRCK < 70) or WPCK < 75
Minor Rehab	(RIDE <= 70 or RUT <= 70 or CRCK <= 70 or WPCK <=75) And RUT >= 50
Major Rehab	RIDE <= 50 or RUT <= 50 or CRCK <= 50 or WPCK <= 60
Reconstruction	WPCK <= 50

Table 13: Concrete and Asphalt Treatment Trigger Mechanisms

When a treatment is selected, the condition index is reset to reflect additional life gained from the treatment. Each condition can be reset a different amount, depending on the benefit gained from the treatment. Subsequent deterioration of the pavement can also be modified according to the treatment applied.

Treatment Name	Cost (sq. yd.)	Reset Value
Chip Seal	$1.90	Sets CRCK to 100, resets RIDE & RUT by 10% and WPCK by 2.5%
Open Graded Seal	$7.10	Sets CRCK to 100, resets RIDE & RUT by 18% and WPCK by 5%
Functional Repair	$8.00	Sets CRCK to 100, resets RIDE & RUT by 30% and WPCK by 5%
Asphalt Minor	$10.00	Sets CRCK to 100, resets RIDE & RUT by 45% and WPCK by 5% (or at
Asphalt Major	$30.00	Sets CRCK, RIDE & RUT to 100 and resets WPCK by 40% (or at least 90)
Asphalt	$75.00	Sets all indices to 100
Concrete Preventive	$6.50	Resets RIDE, FALT & JTSP by 20%
Concrete Grinding	$7.20	Resets RIDE & FALT by 50% and JTSP by 25%
Concrete Minor	$13.50	Resets RIDE & FALT by 40% and JTSP & CRCK by 35%
Concrete Major	$90.00	Sets all indices to 100

Table 14: Treatment Costs and Resets

3.2.11 PMS Budget Categories

The UDOT PMS utilizes two budget categories for analyzing the pavement network as follows:

- Orange Book

  The Orange Book Budget Category includes contracted minor maintenance and preservation treatments. Historically this program was published in a booklet format with an orange colored cover hence the name of the budget category "Orange Book".

- Blue Book

  The Blue Book Budget Category includes contracted minor and major rehabilitation and reconstruction type treatments.

Historically this program was published in a booklet format with a blue colored cover hence the name of the budget category "Blue Book".

3.2.12 Reporting System Condition

The PMS generates many strategies for each pavement section and compares the benefit of increased life & condition with the treatment costs. The types of treatments selected are influenced by what the model is trying to optimize. This can be set for any single performance measure or any combination of measures. The UDOT PMS optimizes the network using the Overall Condition Index (OCI). A listing of pavement sections and optimum strategies is generated for each year of the analysis based on available budget and reports and graphs are produced.

Treatment strategies focus on maintaining the system condition in the good to fair condition ranges. Treatments in these ranges are the most effective in preventing further deterioration and provide the greatest benefits in terms of costs. After the pavement condition becomes poor or very poor a much more expensive repair is required to bring the pavement back to an acceptable condition level.[27]

The main performance measure used for GASB34 reporting and to report the overall system condition has been the Ride Index, based on half car IRI. This is based on a historical 1 to 5 scale with separate scales for asphalt and concrete pavements. The following list shows the half car IRI values used.

Qualitative Range	RI Index	Asphalt HRI	Concrete HRI
Very Good	4.35 to 5.00	0 to 42	0 to 79
Good	3.55 to 4.35	42 to 65	79 to 103
Fair	2.75 to 3.55	65 to 93	103 to 130
Poor	1.85 to 2.75	93 to 126	130 to 163
Very Poor	1.00 to 1.85	126 to 466	163 to 326

Table 15: Ride Index Performance Measure used to Report Pavement Condition

Performance goals have been set separately for the Interstate system, Arterial system and Collector system. These are to have 90% of the Interstate mileage at a Fair or better condition, 70% of the Arterial mileage at Fair or better, and 50% of the Collector mileage at Fair or better. The following chart shows a historical trend of the pavement condition reported with the RI index.

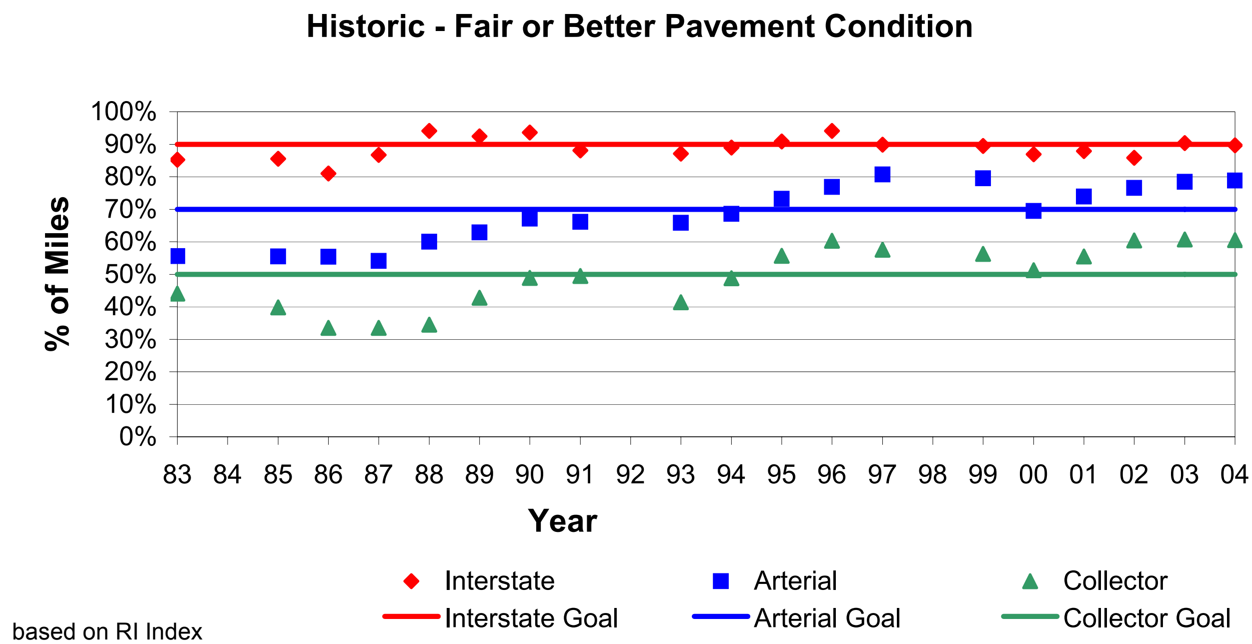


Figure 21: Historic Pavement Condition based on Ride Index

Overall the system wide condition distribution is displayed in Figure 22:

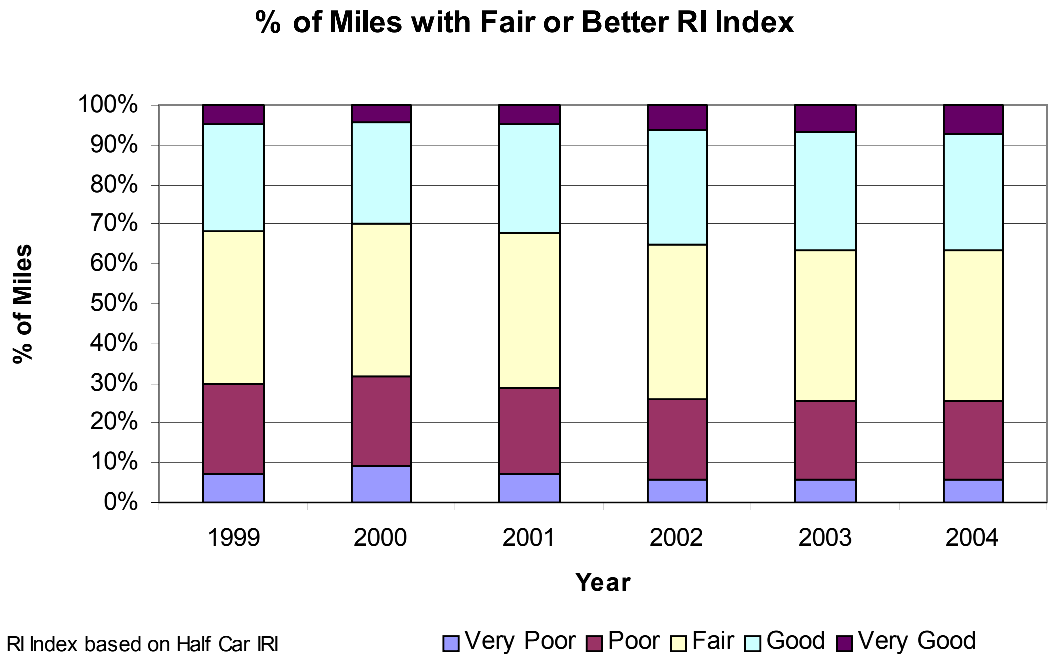


Figure 22: Historic Pavement Condition Distribution based on Ride Index

More recently the concept of reporting Ride Quality has been used within the UDOT model. This model uses the average IRI measure of pavement roughness. The ranges for very good, good, fair, poor and very poor will depend on the posted speed, as well as pavement type. This will report how Utah drivers perceive the pavement condition by how the ride feels and how they expect it to feel. The high speed Interstate would be expected to be much smoother than a lower speed city street with utilities and driveways, so the IRI scales will be set to reflect that expectation.

This can also be reported by the amount of travel on the roadway, expressed as vehicle miles traveled (VMT), instead of miles. The IRI ranges for the Ride Quality Index are displayed in the following tables.

Qualitative Range	Ride Quality Index	Interstate Asphalt	High Speed Asphalt	Mid Speed Asphalt	Low Speed Asphalt
Very Good	90 to 100	30 to 50	34 to 55	38 to 60	41 to 65
Good	70 to 90	50 to 90	55 to 98	60 to 105	65 to 112
Fair	50 to 70	90 to 130	98 to 140	105 to	112 to

				150	160
Poor	30 to 50	130 to 170	140 to 182	150 to 195	160 to 207
Very Poor	0 to 30	170 to 230	182 to 246	195 to 262	207 to 278

Table 16: Proposed IRI Performance Measures for Asphalt Pavements

Qualitative Range	Ride Quality Index	Interstate Concrete	High Speed Concrete	Mid Speed Concrete	Low Speed Concrete
Very Good	90 to 100	65 to 80	68 to 85	72 to 90	76 to 95
Good	70 to 90	80 to 110	85 to 117	90 to 125	95 to 132
Fair	50 to 70	110 to 140	117 to 150	125 to 160	132 to 170
Poor	30 to 50	140 to 170	150 to 196	160 to 195	170 to 208
Very Poor	0 to 30	170 to 215	196 to 231	195 to 248	208 to 264

Table 17: Proposed IRI Performance Measures for Concrete Pavements

When the IRI performance measures are applied to the UDOT network in dTIMS CT, the following performance level is achieved.

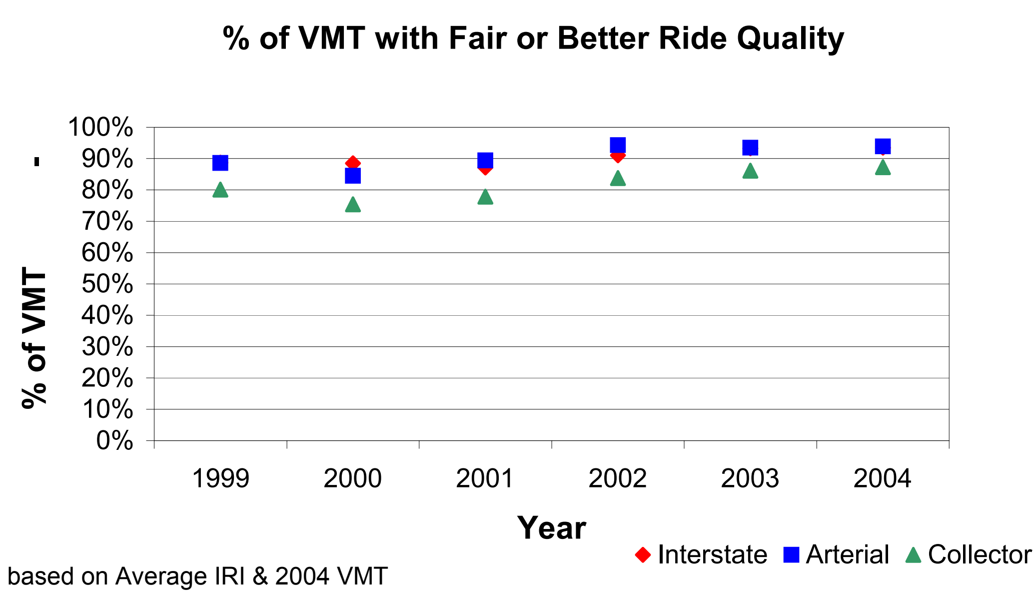


Figure 23: Historic Pavement Condition based on dTIMS CT IRI Performance Measure

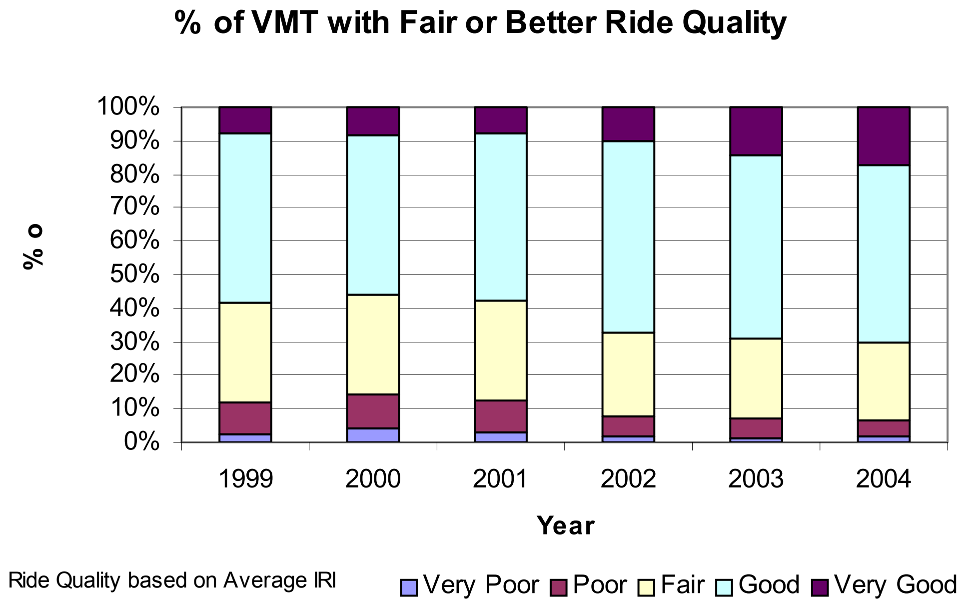


Figure 24: Historic Pavement Condition based on dTIMS CT IRI Performance Measure

3.2.13 Using the Pavement Management System for this Study

For the purposes of this study Deighton and UDOT configured UDOT's dTIMS CT PMS as a research tool to determine the effects of UDOT's preservation and rehabilitation policies and performance goals on each of the variables included in the study and described in Section 2.4.

Many different analyses were completed that enable UDOT to compare current policy against various alternative rehabilitation and preservation strategies. The alternative strategies and the results of the analysis are described later in this report once the study variables are introduced and discussed.

4. Study Factors

4.1 User Costs

There are a number of costs associated with driving a vehicle. These costs can include the following:

- Purchase price;
- Insurance;
- Fuel;
- Repairs;
- Travel time delay.

These user costs are all influenced by the conditions under which the vehicle is being operated. The report will identify ways to measure these costs so they can be used to quantify benefits to evaluate changes we can make in the highway network. We will look at the effects of pavement roughness, construction delay due to projects, and improved safety.

The following User Cost sub-sections of the study were researched and developed by Gary Kuhl, UDOT Pavement Management Engineer.[28] These models were developed to be a very simplistic way to evaluate the affects of user costs on the traveling public. Many different sources and references were used in the preparation of this section and they are referenced once here for simplicity.[29] [30] [31] [32] [33] [34] [35] [36]

4.1.1 Baseline Operating Costs

There are fixed costs for owing a vehicle, and there are variable costs for actually driving a vehicle. Cost will be developed for passenger vehicles (autos, SUVs, and pick ups) and commercial trucks (single unit trucks and semis). In future studies, these vehicle groups can be further subdivided when more detailed cost information becomes available.

For 2005, the AAA estimates ownership and operating cost at 56.1 cents per mile for a new passenger car. This includes insurance, license, registration and taxes, financing, as well as the other less significant operating costs. This average new car was shown to depreciate at 25.9 cents per mile. Routine maintenance and tires were estimated to cost 5.9 cents per mile. Since one can not influence most of the ownership costs, the report will only be looking at the operating costs affected by driving the vehicle. These costs can be measured in terms of fuel consumption, maintenance & repairs, tire wear, and additional depreciation.

4.1.2 Fuel Consumption:

Fuel consumption is one of the most obvious operating costs. With EPA reporting 2005 automobiles averaging around 21.0 mpg, the study will use 18 mpg for our mixed fleet of older cars and pick-ups. For trucks the report will be using 7 mpg. The price of fuel has dramatically increased in the past year and appears to have set a new baseline around $2.00 / gallon. For the purposes of this study, the analysis will use 11.1 cents/mile for autos & 28.6 cents/mile for trucks.

4.1.3 Maintenance and Repair

IntelliChoice ® publishes detailed information annually for maintenance and repair cost on common vehicles. Manufactures also have published maintenance schedules that were used to develop these costs. Adjusted for inflation the analysis will use 3.8 cents per mile for autos and a truck cost of 11.5 cents per mile.

Tire costs were also taken from IntelliChoice®. These are 1 cent per mile for autos and 3.5 cents for trucks.

4.1.4 Depreciation

Depreciation cost was derived from the N.A.D.A. publications and adjusted for the age and type of vehicle. This was further evaluated to remove the age-based depreciation, and only included the difference due to driving. Trucking industry information was used to obtain a cost for trucks. This study will use 7.2 cents per mile for autos and 8.7 cents per mile for trucks.

4.1.5 Base Line Vehicle Operating Costs

When the individual items are summarized and totaled, the base line vehicle operating costs (VOC) for automobiles and trucks are displayed in Table 18.

Category	**Autos (Cents / Mile)**	**Trucks (Cents / Mile)**
Fuel	11.1	28.6
Maintenance & Repair	3.8	11.5
Tires	1	3.5
Depreciation	7.2	8.7
Totals (less fuel)	23.1 (12)	52.3 (23.7)

Table 18: Base Line Vehicle Operating Costs

4.1.6 Effects of Pavement Condition on Base Line VOC

The research for this study used a 2003 Minnesota DOT Research study that looked at the Per-mile Costs of Operating Automobiles and Trucks for the basis of calculating the benefits of improved smoothness. The study also investigated a Texas Research and Development Foundation published a 1982 study that looked at the impacts of pavement roughness on operating cost. Also considered was a FHWA published study that investigated operating cost, fuel consumption, and the effects of pavement condition.

The additional cost of pavement roughness will be treated as a percentage increase in the baseline cost. For this study, the research looked at the typical range of roughness for paved state highways measured in terms of IRI, in inches/mile. For smoother roads with lower IRI there will be no additional cost. An incremental increase will be applied for IRI over 80 in/mile.

Minnesota based their roughness adjustment on the Texas estimates, with some reductions for smoother roads, and then used the same adjustment factor for autos and trucks:

PSI	IRI (inches/mile)	IRI (m/km)	Adjustment
≥ 3.5	80	1.2	1.00
3.0	105	1.7	1.05
2.5	140	2.2	1.15
≤ 2.0	170	2.7	1.25

Table 19: Minnesota Baseline Roughness Adjustment Factors

The PSI shown in the table refers to a common roughness measure, the Present Serviceability Index. Some documents refer to a PSR, or Present Serviceability Rating, which is the same thing. UDOT uses the International Roughness Index (IRI) to measure surface roughness. The relationship between IRI & PSR used is

$$PSR = 5e \wedge -0.0041(IRI).$$

The FHWA 1982 study paper was also be used to help develop UDOT's adjustment factor. This study had separate costs for small, medium, large autos, pick-ups, 2 axle single unit trucks (2A SU), 3 axle single unit trucks (3A SU), 4 axle semis (2 - S2), and the most common 5 axle semis (3 - S2). Different costs were developed depending on grade and speed for each level of pavement condition. The figures listed in Table 20 and Table 21 are in 1980 cents/mile for the 0% grade and 55 mph, for the different SI levels of pavement condition.

SI		**Autos**			**Single Units**		**Semis**	
COND	**Small**	**Medium**	**Large**	**Pick Up**	**2A SU**	**3A SU**	**2 - S2**	**3 - S2**
4.5	10	12.6	13.4	12.7	26.1	37.2	30.8	35.7
4.0	10.2	12.9	13.7	13.1	26.4	37.9	31.6	36.6
3.5	10.6	13.3	14.2	13.5	27	39	32.7	37.9
3.0	11.1	13.9	14.9	14.2	27.7	40.3	34.2	39.6
2.5	11.9	14.7	15.9	15.2	28.8	42.2	36.4	42
2.0	12.9	16	17.3	16.7	30.1	44.5	39.3	45.2
1.5	13.8	17.1	18.5	18	31.9	47.7	43.5	49.9
1.0	15	18.4	20.1	19.5	34.4	52	50.1	57.3

Table 20: FHWA 1982 Study VOCs

SI	**Auto**	**SU**	**Semi**
4.5	12.2	31.7	35.7
4	12.5	32.2	36.6
3.5	12.9	33.0	37.9
3	13.5	34.0	39.6
2.5	14.4	35.5	42.0
2	15.7	37.3	45.2
1.5	16.9	39.8	49.9
1	18.3	43.2	57.3

Table 21: FHWA 1982 Average VOC for Automobiles, Single Units and Semis

From this cost data the UDOT adjustment factors were developed, with a percent difference from the SI = 3.5:

SI	**IRI**	**Auto Adjustment Factor**	**Single Unit Adjustment Factor**	**Semi Trailer Adjustment Factor**
3.5	87	1.00	1.00	1.00
3.0	125	1.05	1.03	1.04
2.5	169	1.12	1.08	1.11
2.0	223	1.22	1.13	1.19

1.5	293	1.31	1.21	1.32
1.0	392	1.41	1.31	1.51

Table 22: UDOT Vehicle Operating Cost Adjustment Factors

The Minnesota and FHWA costs factors were plotted against average IRI to see how they compared.

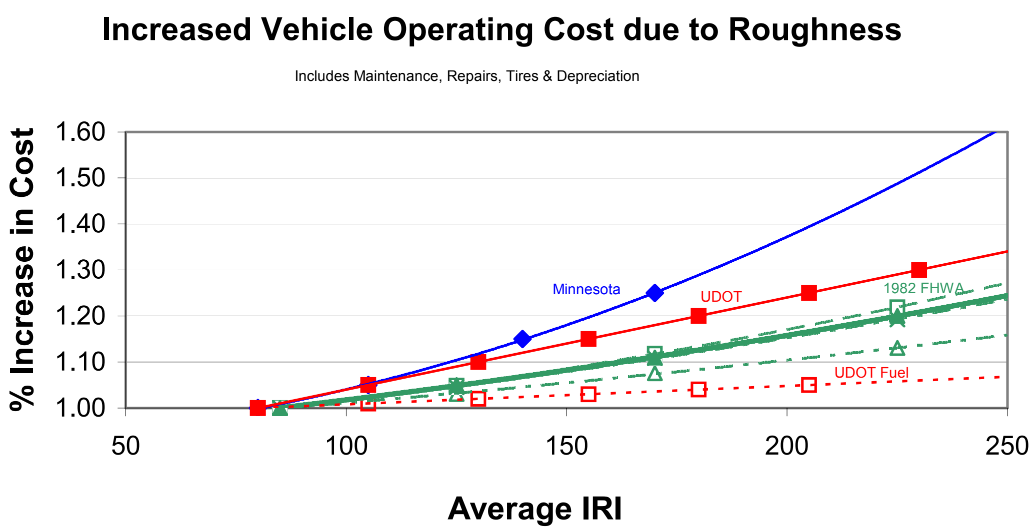


Figure 25: Vehicle Operating Cost Comparison

Based on this information from Minnesota and FHWA, UDOT will use a simplified straight-line adjustment between the FHWA values and the Minnesota values for all vehicles. There will be a separate adjustment due to fuel cost.

Although there is available evidence that pavement roughness does not significantly impact fuel usage, it will be included for our study at a reduced level. Many factors affect fuel consumption more than pavement condition; like grade, speed, age and type of vehicle, etc. But as it is such a large percentage of the operating cost, even a small affect from improved smoothness will have a measurable benefit. Research at the University of North Florida suggested that a

5% improvement in fuel consumption with a reduction in IRI from 200 to 80 in/mi, and upwards of 7% if improved to an IRI of 40 in/mi.

The final adjustments for vehicle operating costs for non fuel items and fuel items are displayed in Table 23.

IRI (inches/mile)	Non Fuel VOC Adjustment Factor	VOC Fuel Component Adjustment Factor
80	1.00	1.00
105	1.05	1.01
130	1.10	1.02
155	1.15	1.03
180	1.20	1.04
205	1.25	1.05

Table 23: Final UDOT Vehicle Operating Cost Adjustment Factors for Roughness

To put these additional roughness expenses in perspective, a typical car that travels 12,000 miles per year will incur $ 1,440 in normal operating expenses using these cost values. The effect of this roughness adjustment says that if it was driven on a very rough road with an IRI of 205 all year, there will be an additional $ 360 of wear and tear on the vehicle (additional repairs, tire wear, and overall reduction in value). The fuel consumption will also increase an additional 5%, costing an additional $67 to the vehicle owner. These additional expenses are unrealistic for an individual vehicle. Nobody would drive all year on a very rough road like this, which would lead to individual costs being much less. But these additional user costs are substantial when applied to all of the driving on the State system.

We can apply these roughness adjustment factors to the baseline cost and calculate the total additional user cost due to pavement roughness. Using the 2004 vehicle miles of travel for autos and trucks on the state highway system, the measured IRI, and these baseline cost values, we calculate an **additional** user cost of $111.2 million annually caused by increased roughness.

Simply stated, our system roughness is adding about $111 million a year to the driving costs of Utah's drivers. This works out to be about a 2.5% increase to the baseline operating cost.

We can now use this information to see where the greatest benefits can be achieved with improved smoothness.

		Asphalt Pavements			**Concrete Pavements**	
Highway Class	**Annual User Cost**	**% of Total User Cost**	**Total Miles**	**% of Total Miles**	**Average User Cost/Mile**	**Average IRI**
Interstate	$47,469,659	42.7%	936.2	16.0%	$50,704	83
Arterial	$52,340,350	47.1%	3044.1	51.9%	$17,194	97
Collector	$10,707,055	09.6%	1837.3	31.4%	$5,828	112
Local	$646,220	00.6%	42.0	0.7%	$15,369	129
Total	$111,163,285	100.0%	5,860	100.0%	$18,971	105.25

Table 24: Vehicle Operating Costs by System Class

When Table 24 is investigated, the results clearly indicate that the Interstate system has a much higher percentage of the VOC than the other systems that have a much higher percentage of the roadway network. This can be expected due to the much higher volumes of traffic, especially the high volumes of truck traffic on the Utah interstate system. Much of this increase in vehicle operating costs on the interstate system is due to the higher amount of concrete interstate pavements which tend to be slightly rougher and have a higher IRI than flexible pavements.

The following bar chart shows how the distribution of IRI varies between the functional classes.

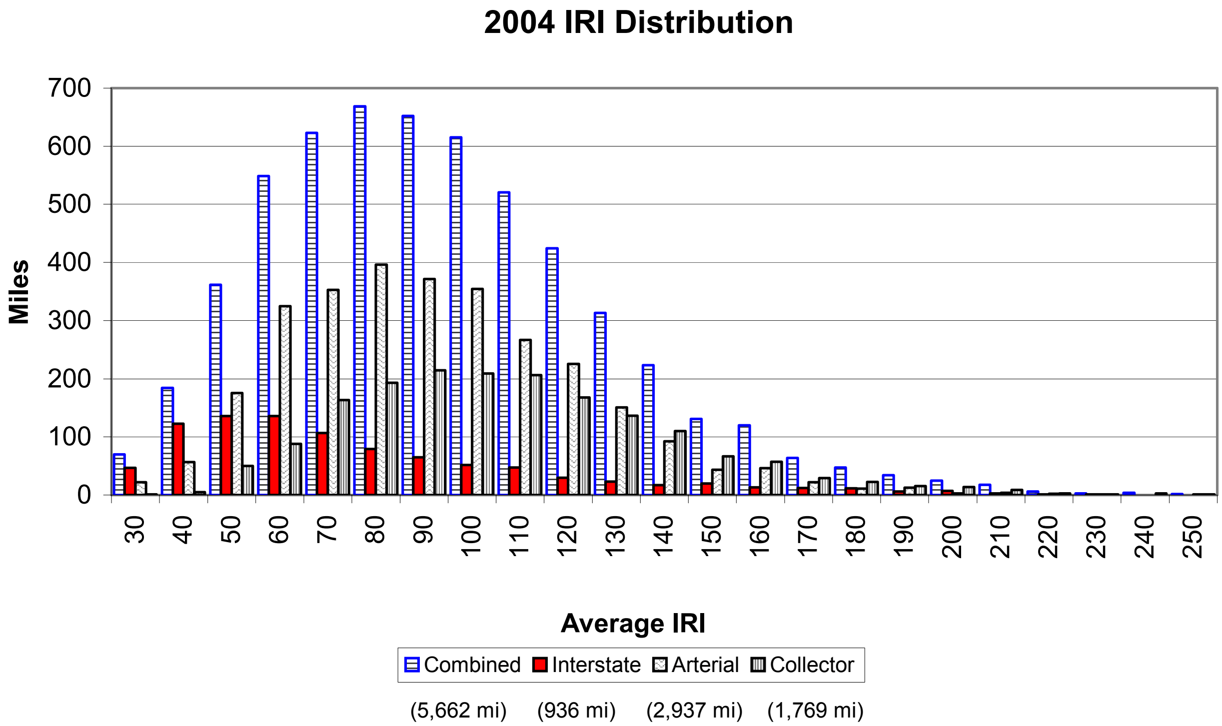


Figure 26: IRI Distribution across the State Highway Network

The following table shows how the pavement type affects this user cost. The concrete network is approximately 6% of the Utah highway network but accounts for 47% of the increased vehicle operating costs due to roughness.

Class	Cost	Miles	Cost/Mile	Ave IRI	Cost	Miles	Cost/Mile	Ave IRI
Interstate	$7,920,000	646	$12,300	64	$39,550,000	290	135,000	126
Arterial	$40,475,000	2974	$13,600	96	$11,865,000	70	170,000	125
Collector	$10,675,000	1822	$5,900	112	$25,000	1	30,000	133
Local	$645,000	42	$15,400	129				
Total	**$59,715,000**	**5,485**	**$11,800**	**97**	**$51,440,000**	**361**	**$83,750**	**125**
Percent	**53%**	**94%**			**47%**	**6%**		

Table 25: Asphalt versus Concrete VOC comparison

The following bar chart shows how the IRI for Asphalt and Concrete compares.

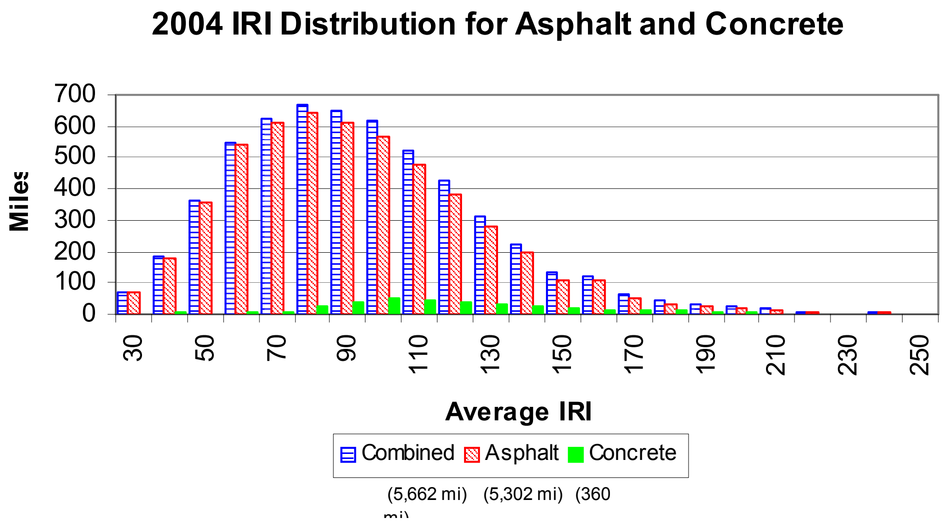


Figure 27: Asphalt and Concrete Distribution

The Vehicle Operating Cost models were implemented within dTIMS CT to allow UDOT to track the annual vehicle operating costs per section and analysis strategy. This enables UDOT to determine the effectiveness of each strategy in reducing operating costs due to increased roughness.

4.2 Safety

As a pavement surface ages the environmental conditions and constant traffic loadings wear down the driving surface and cause some of the pavement surfaces to become smooth. This smoothening action on the roadway driving surface reduces friction and the ability of vehicle tires to grip the roadway. This loss of friction can contribute to increased accident rates and increased accident costs across the UDOT highway network.

A locked-wheel skid trailer is used to measure the skid resistance throughout the UDOT highway network. This information is maintained within UDOT and is investigated for project prioritization but is not used currently as a treatment triggering mechanism within the PMS. One skid test is completed within each mile of the network on a two year cycle. The Skid performance index used within dTIMS CT encompasses a range of values from 0 to over 50 where 50 represents a pavement section with excellent friction and a value of 0 represents a pavement that has little or no friction.

4.2.1 UDOT Highway Network Accident Costs Statistics

Crash reports for vehicle crashes occurring on the UDOT highway network are forwarded to UDOT for central collection and analysis. These crash reports are entered into a database called the Central Accident Reporting System (CARS). Crash reports are completed by law enforcement officers at crash sites throughout the UDOT highway network when a crash involves injuries, fatalities or at least $1000 in property damage or when other factors warrant a report such as jurisdiction legislation or special circumstances at the discretion of the investigating officer.

The Department of Public Safety produces an annual report of Crash Summary statistical data through a project entitled CODES (Utah Crash Outcome Data Evaluation System) in cooperation with the Intermountain Injury Research Center and the University of Utah School of Medicine.[37]

Crash rates within Utah have fluctuated throughout the last 30 years but overall the trend has seen a reduction in the number or crashes and the number of injury and fatal crashes. Figure 28 illustrates the crash statistics from 1972 to 2002. It is important to note that in 1997, private property accidents (10% of the total yearly accidents in Utah) were removed from CARS and no longer included in CODES.

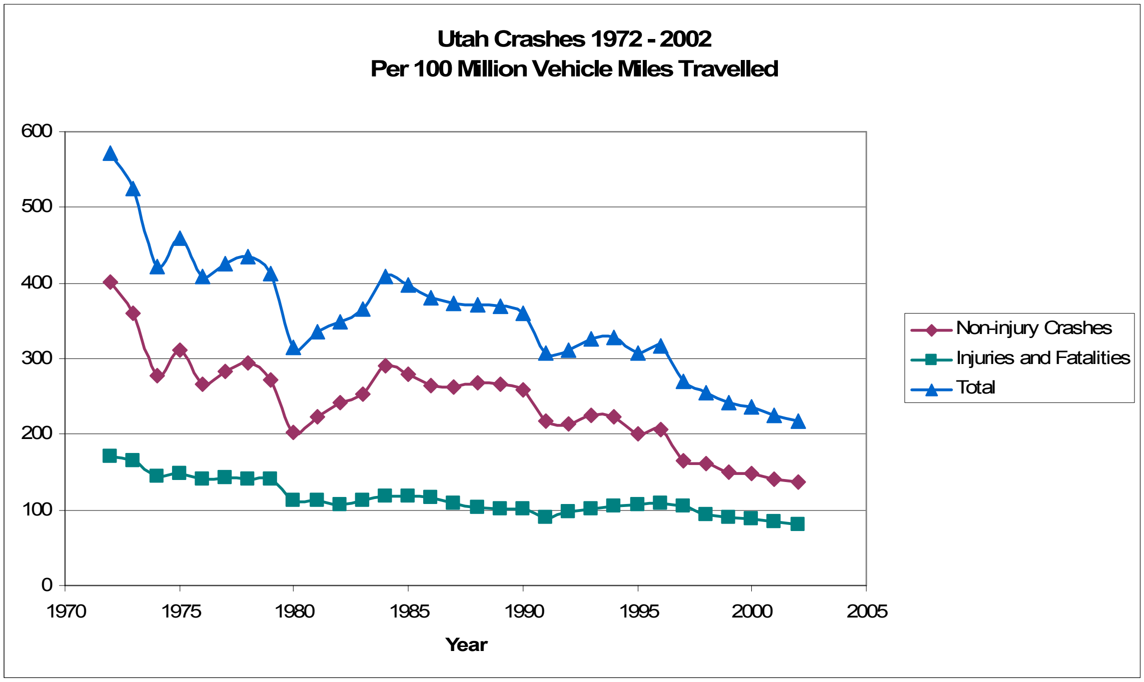


Figure 28: Utah Crashes 1972-2002

4.2.2 Accident Costs versus the UDOT Skid Number

In order to account for accident costs within the Good Roads Cost Less Study, a study of the accident records was performed by Doug Anderson, UDOT,[38] to determine the effects of pavement condition on the rate of accidents and the costs of those accidents occurring upon the UDOT highway network.

One of the outputs of the study was the average cost of accidents per crash based on functional classification as displayed in Table 26:

Highway Classification	Average Cost per Crash	Skid Threshold Values at which accident rates increase
Interstate	$44,200	30
Urban Non-Interstate	$25,700	40
Rural Non-Interstate	$62,800	40

Table 26: UDOT Average Cost per Crash

Another component of the study determined that the accident rates increased when the skid number fell below the threshold values indicated for each highway classification as displayed in Table 26.

A relationship was developed[39] that linked accident rates to the skid number as indicated within the Figure 29 and an increased rate of accidents based on the skid number which is shown in Figure 30:

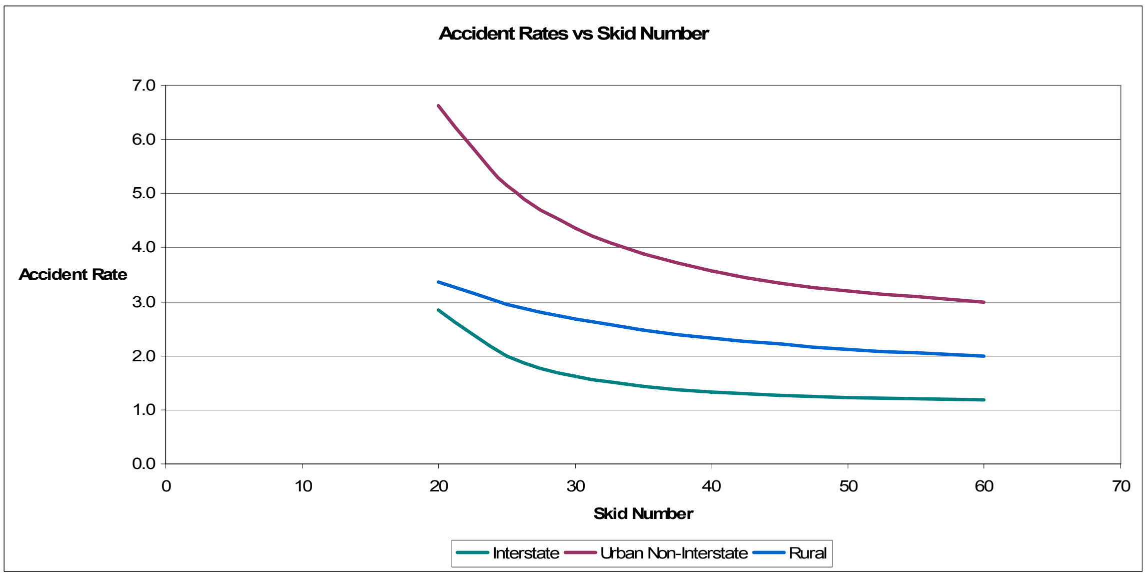


Figure 29: Accident Rates versus the UDOT Skid Number

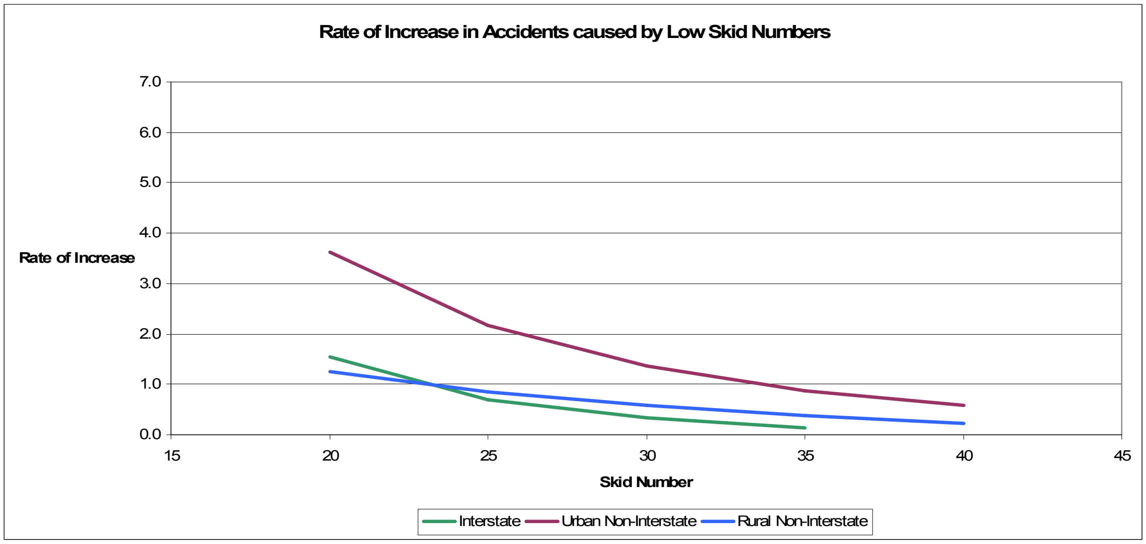


Figure 30: Rate of Increase in Accidents caused by Low Skid Numbers

Examples of the accident costs using various skid number values for each functional classification are shown in Table 27.

Segment Length	Functional Class	Average Cost / Crash	Average Annual Daily Traffic	Skid Index	Accident Rate	Delta Accident Rate	Annual Accident Cost	Increased Accident Cost
5.0	Rural	62,800.00	10000	50	2.122	0.000	$2,432,253	$0
5.0	Rural	62,800.00	10000	40	2.328	0.228	$2,667,834	$261,024
5.0	Rural	62,800.00	10000	30	2.670	0.570	$3,060,469	$653,659
5.0	Rural	62,800.00	10000	20	3.356	1.256	$3,845,739	$1,438,929
5.0	Urban	25,700.00	20000	50	3.200	0.000	$7,335,498	$0
5.0	Urban	25,700.00	20000	40	3.568	0.571	$8,177,710	$535,275
5.0	Urban	25,700.00	20000	30	4.361	1.364	$9,997,303	$1,279,917
5.0	Urban	25,700.00	20000	20	6.630	3.633	$15,196,140	$3,407,467
5.0	Interstate	44,200.00	50000	50	1.230	0.000	$7,048,928	$0
5.0	Interstate	44,200.00	50000	40	1.335	0.000	$7,650,128	$0
5.0	Interstate	44,200.00	50000	30	1.630	0.330	$9,338,380	$1,329,329
5.0	Interstate	44,200.00	50000	20	2.840	1.540	$16,273,904	$6,210,701

Table 27: Accident Cost Examples

When the dTIMS CT PMS was configured for the Good Roads Cost Less Study, Deighton included only the Increased Accident Cost values within the analysis. If the skid numbers were above the threshold values indicated in Table 26, the increased accident cost as a result of the skid number would be 0.

Certainly within any specific corridor a low skid number could affect the safety of the facility which is based on many different factors. The magnitude of the skid number affects the stopping distance of a vehicle during a traffic conflict, especially when the pavement is wet. The number and severity of the crashes observed over time depends not only upon the skid number but upon the types of conflicts, running speeds, vehicle types in the traffic stream, highway geometrics, traffic control devices present, weather, and many other factors.

For analysis in this study, highway system averages have been used which reflect the overall safety of all of the corridors within each highway functional classification. Good roads, with acceptable skid values, have been shown to have a definite positive impact on the cost to highway users in the form of reduced accident costs.

For the purposes of the study, the SKID number in the dTIMS CT PMS was deteriorated at 2% per year throughout the analysis period.

4.3 Treatment Delay Costs

An important consideration within asset management planning is the amount of delay imposed upon the traveling public due to maintenance and rehabilitation projects occurring within the network. The benefits of the maintenance and rehabilitation projects must be evaluated against the delay cost to the public that will be inconvenienced by undertaking the project. As an example consider the difference between a minor maintenance operation which may not impose any considerable delay on the public at all and a major reconstruction project which may impose considerable hours of delay throughout the lifespan of the project.

The impacts of the treatment delay cost across the network could be substantial depending on the various strategies UDOT uses to maintain the highway network. If UDOT were to adopt the practice of "Worst First" planning and programming where the worst roads in the network are fixed, the delay costs to the public would be substantial as major reconstruction and rehabilitation projects would be used more often than minor maintenance and preservation treatments as the "worst first" roads would require major, not minor treatments. If UDOT were to maintain the network using only minor maintenance and preservation treatments, the delay costs would be nominal but the condition of the network would deteriorate overtime to the point where minor maintenance and preservation treatments would not stop the deterioration of the network to a poor condition. Clearly the treatment delay costs should be an important consideration within the planning and programming of maintenance and rehabilitation activities across the highway network.

The following three sub-sections of the study were researched and developed by Gary Kuhl, UDOT Pavement Management Engineer.[40] These were developed to be a very simplistic way to evaluate user cost for different types of typical projects with the system level data in the model.

4.3.1 Delay costs per Vehicle

Delay costs per vehicle have been calculated within the study based upon a per hour figure for three difference vehicle classifications as follows:

Vehicle Classification	Delay Cost Per Hour
Automobiles, Motorcycles, Light Trucks	**$12.00 / hour**
Single Unit Trucks	**$24.00 / hour**
Combination Trucks	**$28.00 / hour**

Table 28: Hourly Delay Costs by Vehicle Type

The hourly costs are estimated from various sources and represent conservative estimates for Utah. UDOT Planning developed the 12 $/hr rate for passenger cars from a study of other states and related it to the local economy as 75% of the average hourly wage. The FHWA Highway Economic Requirements System model uses a figure of $32.50 per hour while other research suggests between $60 and $70 per hour.[41]

4.3.2 Calculating Delay Cost for Highways with 2 Lanes

The study assumed that when maintenance and rehabilitation projects were completed on two lane highway facilities, one lane would be closed and that a pilot car and flagging would be used to control traffic through the project limits.

No distinction between Urban or Rural projects was developed. Urban projects provide more options to avoid delay, but have associated longer route and additional congestion costs on alternate facilities. Rural routes typically have higher speeds and more difference in travel time through a project.

UDOT used the number of vehicles affected, hours of delay per vehicle and type of vehicle delayed to estimate this User Cost.

The number of vehicles affected is a function of the number of days for the project times a portion of the AADT. UDOT estimated the length of time required to complete a project per lane mile on a two lane facility as follows:

Treatment Description	**Project Time (days / lane mile)**
Concrete joint seal and spot grind	1
Concrete grind and seal	3
Concrete minor rehab (dowel, jack, replace)	5
Concrete major rehab / replacement	10
Asphalt chip seal	0.5
Asphalt open graded seal / milling	2
Asphalt functional repair (spot repair, thin overlay)	4
Asphalt minor rehab (mill and replace)	6
Asphalt major rehab (structural overlay / milling)	8

Asphalt reconstruction	10

Table 29: Estimated Treatment Project Time

UDOT estimated that approximately 75% of the AADT would be affected by the project and that 25% of the AADT would travel over the project section in off-peak hours and experience little if any delay.

UDOT estimated the number of minutes of delay for each vehicle as a function of the daily traffic, based on the basic assumption that the more traffic there is, the longer the delay would be. For a typical work zone of a couple miles this is:

Average Annual Daily Traffic	Average Delay
5,000	10 minutes
10,000	20 minutes
15,000	30 minutes

Table 30: Average Delay based on Daily Traffic

This relationship was simplified to be AADT/500 for minutes or AADT / 30,000 for delay in hours, recognizing this may well over estimate typical delay, as other methods would be used during heavy traffic to minimize this delay.

Once these factors and assumptions were determined, UDOT developed the following equation to calculate delay costs on two lane highways:

Cost= (AADT / 30,000 * 0.75 * AADT) * (# Days * Length * # Lanes) * % Autos * $12.00
+ (AADT / 30,000 * 0.75 * AADT) * (# Days * Length * # Lanes) * % Single Trucks * $24.00
+ (AADT / 30,000 * 0.75 * AADT) * (# Days * Length * # Lanes) * % Combo Trucks * $28.00

Table 31 presents an example project delay costs for a 5 mile major asphalt rehab project with various levels of AADT and 20% trucks:

Lane Miles		Time	AADT	AADT %			Delay Cost			
Miles	Lanes	Days/Ln Mi		Cars	Singles	Combos	Cars	Singles	Combos	Total
5.0	2	8	2500	80	5	15	$61,440	$7,680	$26,880	$96,000
5.0	2	8	5000	80	5	15	$122,880	$15,360	$53,760	$192,000
5.0	2	8	7500	80	5	15	$184,320	$23,040	$80,640	$288,000
5.0	2	8	10000	80	5	15	$245,760	$30,720	$107,520	$384,000
5.0	2	8	12500	80	5	15	$307,200	$38,400	$134,400	$480,000

Table 31: Project Delay Costs – 2 Lanes

4.3.3 Calculating Delay Cost for Highways with 3 or More Lanes

The calculation of delay cost for highways with more than 2 lanes will have some different assumptions. It will be assumed that traffic will be maintained in both directions. The primary delay will be from a reduced travel speed through the work zone. The same number of days per lane mile will be used.

The reduced travel speed will delay traffic in both directions. This will be assumed to be a 10mph reduction for a typical project. A reduction from 60 mph to 50 mph would result in an additional 0.20 minutes / mile of travel.

The closed lane in the working direction will cause additional delay during peak periods due to the reduced capacity. It was assumed this peak period delay would affect 25% of the urban traffic & 15% of the rural traffic.

This peak period delay with one lane closed in the working direction depends on the volume compared to the reduced capacity, as estimated below:

AADT		Peak Hour Volume		Peak Direction Volume		V/C *		Estimated Total Delay	
Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban		
		10%	8%	70/30 split	60/40 split			Rural	Urban
0	0	0	0	0	0			0	0
5000	5000	500	400	350	240	0.23	0.32	0	0
10000	10000	1000	800	700	480	0.47	0.64	0	0
15000	15000	1500	1200	1050	720	0.70	0.96	0	5
20000	20000	2000	1600	1400	960	0.93	1.28	5	10
25000	25000	2500	2000	1750	1200	1.17	1.60	10	20
30000	30000	3000	2400	2100	1440	1.40	1.92	15	30
35000	35000	3500	2800	2450	1680	1.63	2.24	20	45
40000	40000	4000	3200	2800	1920	1.87	2.56	25	60

* V/C assuming 1 lane capcaity on rural multilane road = 1,500 vehicles & 750 vehicles on urban multilane road
assume if AADT > 40,000 there will be more than 4 lanes

Table 32: Approximate Delay for more than 2 lanes

These estimated delay minutes were then plotted in Microsoft Excel and a curve fit to the approximate delay values for both Rural and Urban sections.

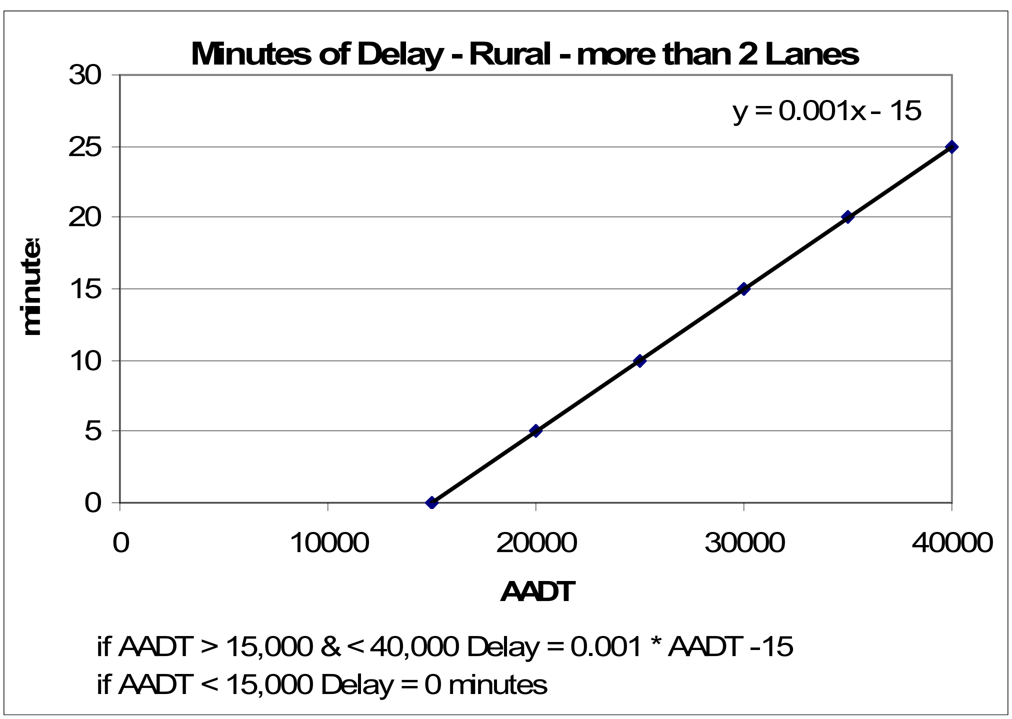


Figure 31: Minutes of Delay – Rural - More than 2 Lanes

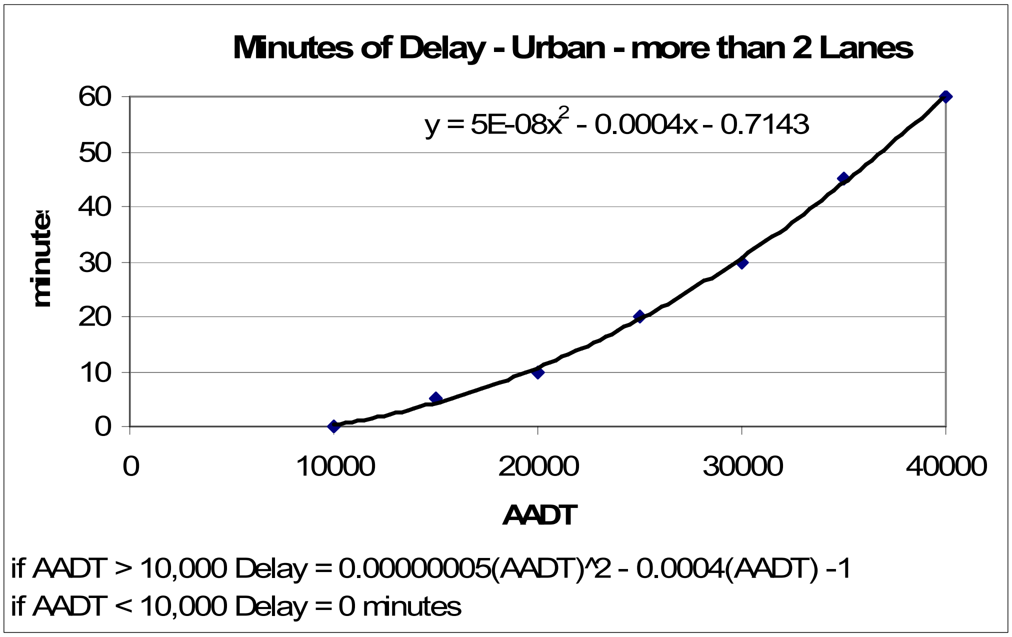


Figure 32: Minutes of Delay - Urban - More than 2 Lanes

The trend lines were then used to develop the rural and urban delay used in the cost expressions:

Rural= ((0.2min/60 * Miles) + (0.15/2 * AADT * RURAL_DELAY)) * (# Days * #Lanes * Length) * % Autos * $12
+ ((0.2min/60 * Miles) + (0.15/2 * AADT * RURAL_DELAY)) * (# Days * #Lanes * Length) * % Singles * $24
+ ((0.2min/60 * Miles) + (0.15/2 * AADT * RURAL_DELAY)) * (# Days * #Lanes * Length) * % Combos * $28

Urban= ((0.2min/60 * Miles) + (0.25/2 * AADT * URBAN_DELAY)) * (# Days * #Lanes * Length) * % Autos *$ 12
+((0.2min/60 * Miles) + (0.25/2 * AADT * URBAN_DELAY)) * (# Days * #Lanes * Length) * % Singles * $24
+ ((0.2min/60 * Miles) + (0.25/2 * AADT * RURAL_DELAY)) * (# Days * #Lanes * Length) * % Combos *$ 28

Table 5 presents an example project delay costs for a 5 mile major asphalt rehab project with various levels of AADT and 15% trucks:

Length	Number	Time	Urban or	AADT	AADT %			Delay Cost			
Miles	of Lanes	Days/Ln Mi	Rural		Cars	Singles	Combos	Cars	Singles	Combos	Total
5.0	4	8	Rural	10,000	85	12	3	$230,633	$71,040	$20,720	$322,393
5.0	4	8	Rural	20,000	85	12	3	$665,267	$199,680	$58,240	$923,187
5.0	4	8	Rural	30,000	85	12	3	$1,609,900	$472,320	$137,760	$2,219,980
5.0	4	8	Rural	40,000	85	12	3	$2,962,533	$860,160	$250,880	$4,073,573
5.0	4	8	Urban	10,000	85	12	3	$218,167	$67,200	$19,600	$304,967
5.0	4	8	Urban	20,000	85	12	3	$885,133	$261,120	$100,800	$1,247,053
5.0	4	8	Urban	30,000	85	12	3	$2,612,900	$754,560	$327,600	$3,695,060
5.0	4	8	Urban	40,000	85	12	3	$6,013,467	$1,720,320	$784,000	$8,517,787

Table 33: Treatment Delay Costs - more than 2 lanes

Additional adjustments were needed for divided highways & highways with more than 4 lanes.

- For divided highways use 50% of the AADT, assuming all of the delay will be on the working side.
- For the few sections with more than 4 lanes, use an AADT reduction factor of Number of lanes/4.

4.4 Agency Costs

Another important cost variable included within the study is the Agency cost which represents the cost to UDOT for maintaining the highway network. These costs will vary significantly based on the strategy for maintaining and rehabilitating the pavement network. Using an example that was illustrated earlier, if UDOT adopts a "worst first" approach to pavement management, UDOT would see an increase in agency costs as the cost of the reconstruction and major rehabilitation treatments are significantly more than the cost of minor maintenance and preservation treatments.

The following table outlines the UDOT PMS treatment costs and their respective budget categories that were used within the study analysis.

Treatment Description	Cost per Square Yard	Budget Category
Concrete joint seal and spot grind	$6.50	Orange Book
Concrete grind and seal	$7.20	Orange Book
Concrete minor rehab (dowel, jack, replace)	$13.50	Blue Book
Concrete major rehab / replacement	$90.00	Blue Book
Asphalt chip seal	$1.90	Orange Book
Asphalt open graded seal / milling	$7.10	Orange Book
Asphalt functional repair (spot repair, thin overlay)	$8.00	Orange Book
Asphalt minor rehab (mill and replace)	$10.00	Blue Book
Asphalt major rehab (structural overlay / milling)	$30.00	Blue Book
Asphalt reconstruction	$75.00	Blue Book

Table 34: dTIMS CT Treatment Costs

The treatment costs in Table 34 represent the square yard unit costs used in the model for this study. These costs have a 3% inflation factor used for the 20 year analysis period. An additional 15% is then included to account for project design and construction engineering expenses. Budget amounts within the analysis are also increased by 3% on an annual basis.

5. The Analysis Results

5.1 Introduction

Deighton and UDOT configured the UDOT's dTIMS CT Pavement Management System (PMS) to analyze many different alternative strategies for maintaining and rehabilitating the UDOT highway network over a 20 year analysis period. The goal of the study was to determine the effects of different policies on the study analysis variables (described in the previous section) and to determine target condition goals for maintaining the UDOT pavement network.

In order to complete the study, Deighton configured twenty different alternative analysis strategies within the dTIMS CT pavement management system. These initial twenty alternative analysis strategies were completed with four initial optimization types and four different budget amounts. That led to 16 different output sets for each strategy.

When the initial information was reviewed and investigated by UDOT and Deighton, several significant changes to the pavement management models were discovered that resulted in the analysis being completed again. Prior to the final analysis being completed, Deighton and UDOT narrowed the number of alternative strategies to 13 with 1 optimization objective function (OCI) and 4 budget scenarios.

5.2 The Alternative Strategies Investigated for the Study

The alternative strategies investigated by UDOT and Deighton are described in the following table and then a brief description of the scenario follows.

Strategy Number	**Strategy Name**
01	Do Nothing
02	Maintenance Only
03	Reconstruction Only
04	Current Model - No Budget Categories
04	Current Model – With Budget Categories
05	Cycle 6 Years and 10 Years - No Budget Categories
05	Cycle 6 Years and 10 Years – With Budget Categories
06	Cycle 6 Years and 12 Years - No Budget Categories
06	Cycle 6 Years and 12 Years – With Budget Categories
07	Cycle 8 Years and 10 Years - No Budget Categories
07	Cycle 8 Years and 10 Years – With Budget Categories
08	Cycle 8 Years and 12 Years - No Budget Categories
08	Cycle 8 Years and 12 Years – With Budget Categories
09	Cycle 10 Years and 10 Years - No Budget Categories
09	Cycle 10 Years and 10 Years – With Budget Categories
10	Condition 10% Less - No Budget Categories
10	Condition 10% Less – With Budget Categories
11	Condition 20% Less - No Budget Categories
11	Condition 20% Less – With Budget Categories
12	No Funding Five Years - No Budget Categories
12	No Funding Five Years – With Budget Categories
13	50% Funding Five Years - No Budget Categories
13	50% Funding Five Years – With Budget Categories

Table 35: Alternative Strategies

Within the dTIMS CT Pavement Management System, the optimization functionality allows the users to choose if they want the optimization to spend the available funding according to the established Budget Categories or without regard to the Budget Categories. In Table 35, the “With Budget Categories” and “No Budget Categories” designation indicates if the Budget Categories were used or not.

If No Budget Categories (NBC) were used within the strategy, dTIMS CT could spend the annual budget without respect to any categories or pots of money. If mathematically optimal, dTIMS CT could spend 100% of the funding on rehabilitation treatments (Blue Book Projects) or 100% of the funding on minor maintenance and preservation treatments (Orange Book Projects). When the strategy was implement With Budget Categories (WBC), the optimization was restricted to using dedicated Blue Book and Orange Book funding amounts without the ability to switch funds between the different budget categories.

The results for the analysis runs were completed and reported using a budget amount of $180 million per year increasing at 3% per year. The total amount of available funding for the $180 million dollar analysis is outlined in the following table:

Alternative Strategy Total Available Budgets	**Total**	**Blue Book Program**	Orange Book Program
No Categories Budget Amount	$4,836,667,408	n/a	**n/a**
Categories Budget Amount	**$4,836,667,408**	**$3,224,444,939**	**$1,612,222,469**

Table 36: Budget Distributions for $180 million scenario

5.2.1 Strategy 01 – Do Nothing

The Do-Nothing strategy was included to demonstrate the deterioration of the highway network and how quickly the highway network pavements deteriorate over time and how quickly the condition of the pavements deteriorates to poor condition. The Do Nothing strategy, though unrealistic for UDOT, demonstrates the tremendous increase in user costs and accident costs when the roughness (RIDE) and friction (SKID) deteriorate.

5.2.2 Strategy 02 – Maintenance Only

The Maintenance Only strategy was included within the analysis to demonstrate the affects on the network if all rehabilitation treatments were removed from the analysis and the routine maintenance program was responsible for maintaining the network in its current condition.

5.2.3 Strategy 03 – Reconstruction Only

The Reconstruction Only strategy was included within the analysis to demonstrate the affects on the network if UDOT adopted a "worst fist" type of programming. Worst First allows the highway network to deteriorate and incorporates reconstruction as the only alternative when the pavements get to poor condition.

5.2.4 Strategy 04 – UDOT Current Model

Strategy 04 represents the current UDOT dTIMS CT Pavement Management System with no changes and serves as the base model. Within the UDOT current model, asphalt treatments have an 8 year treatment timing cycle for both maintenance and rehabilitation type treatments and concrete has a 15 year cycle for any treatment. What this means within the analysis is that a segment receiving an initial treatment will not generate a subsequent treatment for at least 8 years for asphalt pavements and 15 years for concrete pavements.

5.2.5 Strategy 05 – Cycle 6 Years and 10 Years

Strategy 05 modified the UDOT base model and changed the treatment timing cycle to be 6 years for any maintenance treatments and 10 years for any rehabilitation treatments.

5.2.6 Strategy 06 – Cycle 6 Years and 12 Years

Strategy 06 modified the UDOT base model and changed the treatment timing cycle to be 6 years for any maintenance treatments and 12 years for any rehabilitation treatments.

5.2.7 Strategy 07 – Cycle 8 Years and 10 Years

Strategy 07 modified the UDOT base model and changed the treatment timing cycle to be 8 years for any maintenance treatments and 10 years for any rehabilitation treatments.

5.2.8 Strategy 08 – Cycle 8 Years and 12 Years

Strategy 08 modified the UDOT base model and changed the treatment timing cycle to be 8 years for any maintenance treatments and 12 years for any rehabilitation treatments.

5.2.9 Strategy 09 – Cycle 10 Years and 10 Years

Strategy 09 modified the UDOT base model and changed the treatment timing cycle to be 10 years for any maintenance treatments and 10 years for any rehabilitation treatments.

5.2.10 Strategy 10 – Condition 10% Less

Strategy 10 modified the UDOT base model and decreased the condition of every road section within the road network by 10%. This strategy was included to demonstrate what would happen to funding needs if the network was not in as good of a condition as it is today.

5.2.11 Strategy 11 – Condition 20% Less

Strategy 11 modified the UDOT base model and decreased the condition of every road section within the network by 20%. This strategy was included to demonstrate what would happen to funding needs if the network was not in as good of a condition as it is today.

5.2.12 Strategy 12 – No Funding for 5 Years

Strategy 12 modified the UDOT base model and allowed for 0 funding for the first 5 years of the analysis. This strategy was included to demonstrate what would happen to funding needs if the pavement maintenance and rehabilitation funding was cut altogether to supplement other assets or capacity improvements.

5.2.13 Strategy 13 – 50% Funding for 5 Years

Strategy 13 modified the UDOT base model and allowed for 50% funding for the first 5 years of the analysis. This strategy was included to demonstrate what would happen to funding needs if the pavement maintenance and rehabilitation funding was cut to 50% of normal levels in order to supplement other assets or capacity improvements.

5.3 The Analysis Results

As you can imagine, 13 different analyses with multiple budget scenarios generated a significant amount of data and variables to examine. In fact, the UDOT base model Strategy 04 alone generated the following:

- 170,179 strategies

- 680,716 possible selected strategies across all budget scenarios
- 304,580 treatments; and,
- 29,440,967 stored analysis variable values

In order to summarize the results, the report will first examine the results of each of the different strategies and then the report will present the results from a more overall macro level.

5.3.1 Strategy 01 – Do Nothing

5.3.1.1 Results

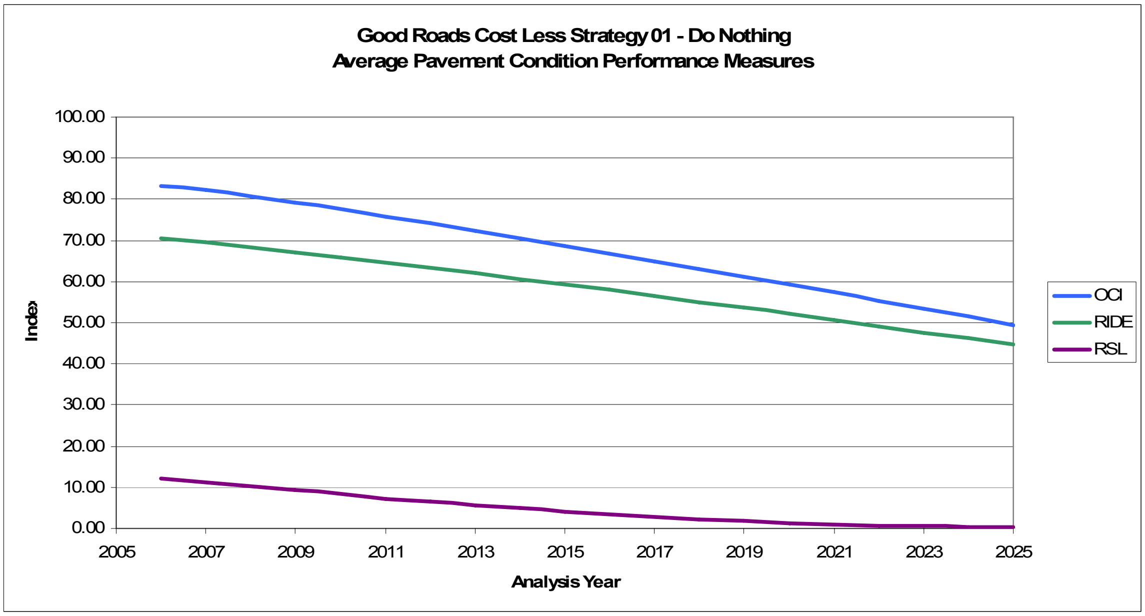


Figure 33: Strategy 01: Do- Nothing Condition Performance Measures

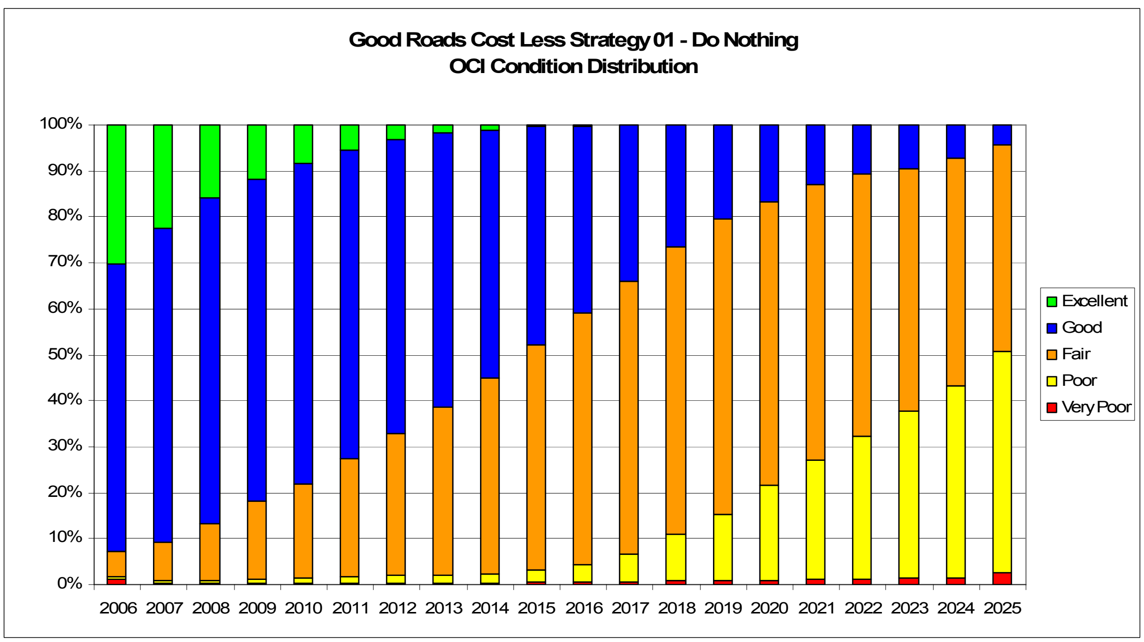


Figure 34: Strategy 01: Do- Nothing OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$14,159,961	$7,174,251,886	$0	$0	$0	$0
2007	$16,351,546	$7,549,730,805	$0	$0	$0	$0
2008	$19,535,999	$7,945,637,395	$0	$0	$0	$0
2009	$24,113,494	$8,363,058,951	$0	$0	$0	$0
2010	$28,959,407	$8,803,204,952	$0	$0	$0	$0
2011	$38,907,844	$9,267,382,430	$0	$0	$0	$0
2012	$48,975,925	$9,756,786,635	$0	$0	$0	$0
2013	$62,203,995	$10,272,688,492	$0	$0	$0	$0
2014	$82,446,154	$10,816,812,472	$0	$0	$0	$0
2015	$112,425,356	$11,390,586,385	$0	$0	$0	$0
2016	$139,416,921	$11,995,802,510	$0	$0	$0	$0
2017	$175,948,117	$12,634,018,389	$0	$0	$0	$0
2018	$223,219,440	$13,307,274,848	$0	$0	$0	$0
2019	$285,927,088	$14,017,303,295	$0	$0	$0	$0
2020	$360,896,581	$14,766,229,915	$0	$0	$0	$0
2021	$433,918,728	$15,553,274,651	$0	$0	$0	$0
2022	$518,655,597	$16,380,664,608	$0	$0	$0	$0
2023	$605,361,510	$17,252,740,978	$0	$0	$0	$0
2024	$712,570,825	$18,159,644,931	$0	$0	$0	$0
2025	$833,227,712	$19,089,921,475	$0	$0	$0	$0
Total	$4,737,222,202	$244,497,016,002	$0	$0	$0	$0

Table 37: Strategy 01: Do- Nothing Economic Impact Performance Measures

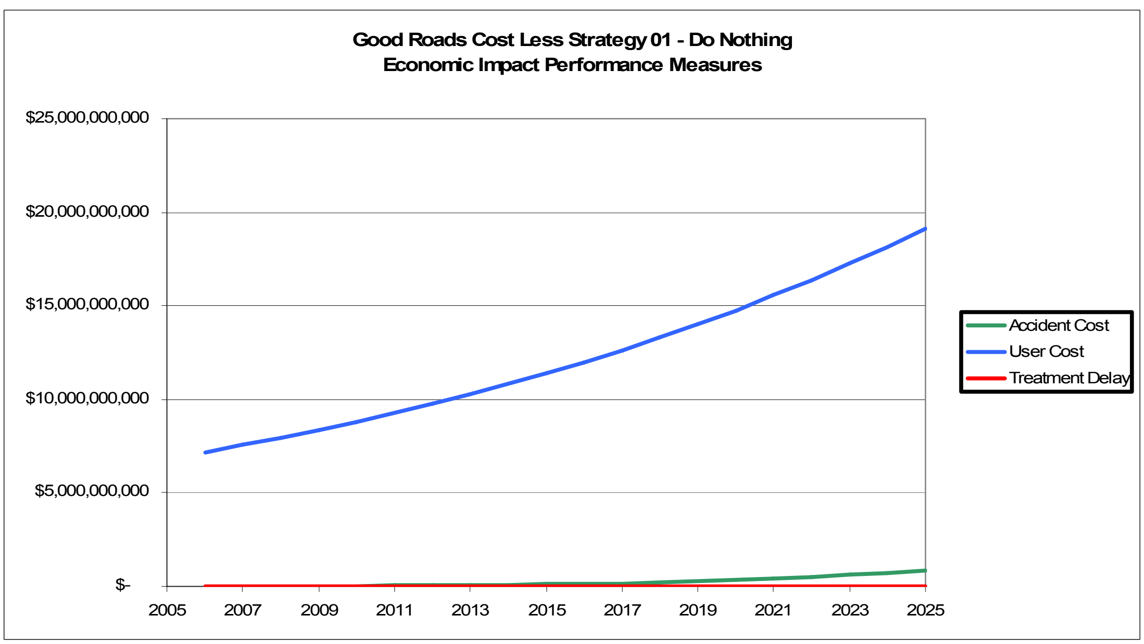


Figure 35: Strategy 01: Do- Nothing Economic Impact Performance Measures

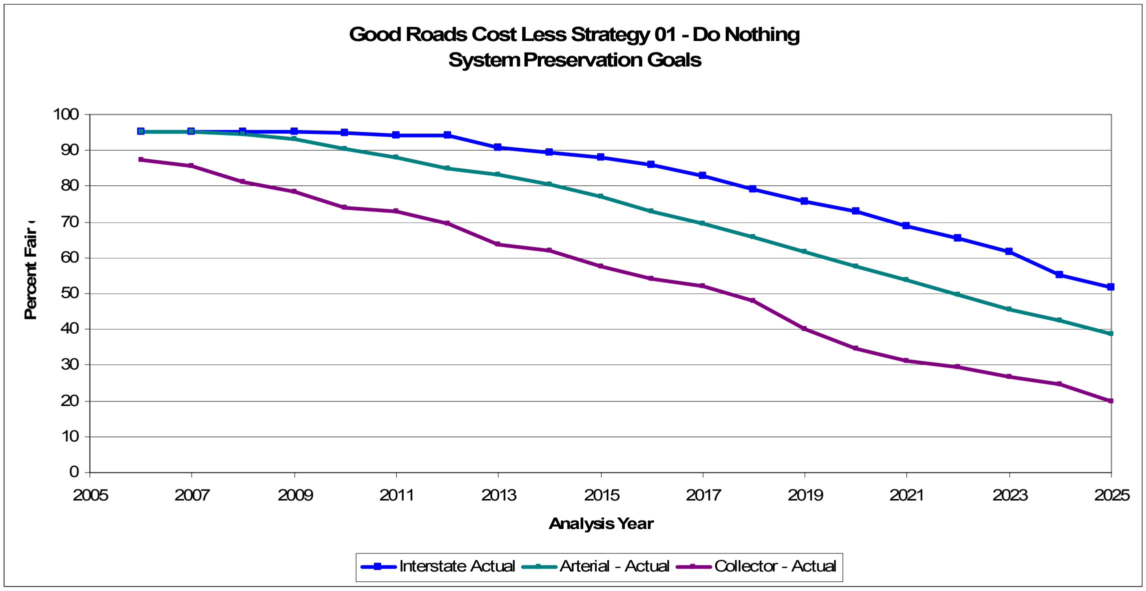


Figure 36: Strategy 01 - Do Nothing System Preservation Goals

5.3.1.2 Discussion

The results achieved from the Do-Nothing analysis were as expected; the condition of the network deteriorated quite quickly and the costs associated with this deteriorating network condition escalated to extremely high values.

During the analysis period the percent of the network in fair or better condition (Figure 36) deteriorated such that by the end of the analysis one half of the highways within each functional classification (Interstate, Arterial and Collector) were in poor or very poor condition. The Remaining Service Life (RSL) of the pavement network deteriorated from 12 to a level of 0 within the analysis period as many of the condition indexes for each highway segment approached the threshold value of 50 due to the lack of any maintenance or rehabilitation treatments (Figure 33).

Increased Accident costs based on the Skid Number and User Costs based on thee RIDE Index reached their highest amounts of all the strategies in the Do Nothing strategy as the Skid Number and the Ride Index deteriorated.

Although the Do Nothing strategy is an unlikely alternative for UDOT, it was included within the study to illustrate the effects of the deteriorating network and how quickly the excellent and good roads turn into fair, poor and finally very poor roadways.

5.3.2 Strategy 02 – Maintenance Only

5.3.2.1 Results

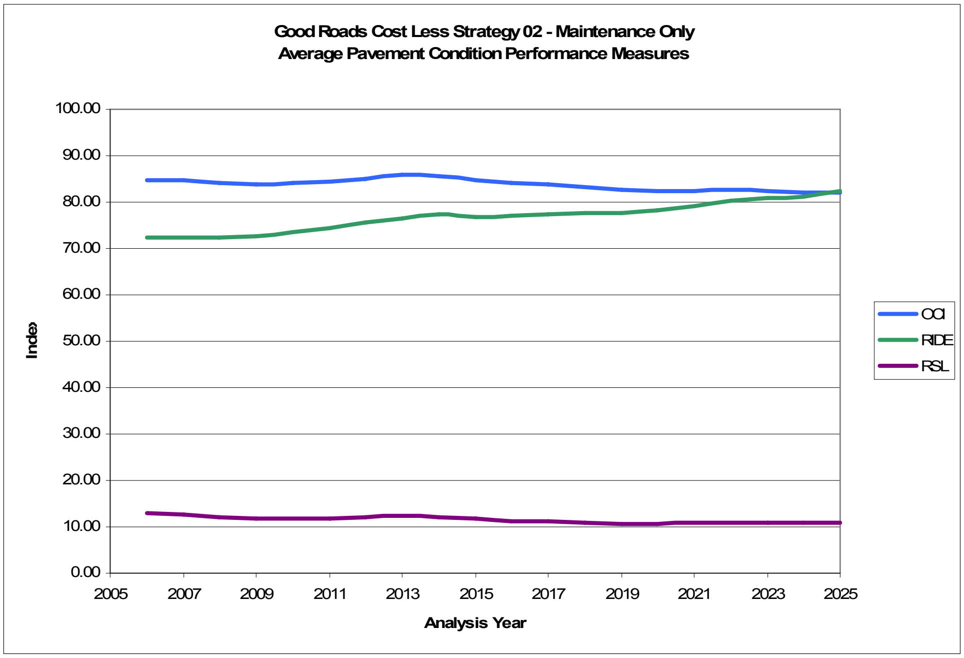


Figure 37: Strategy 02 Maintenance Only Condition Performance Measures

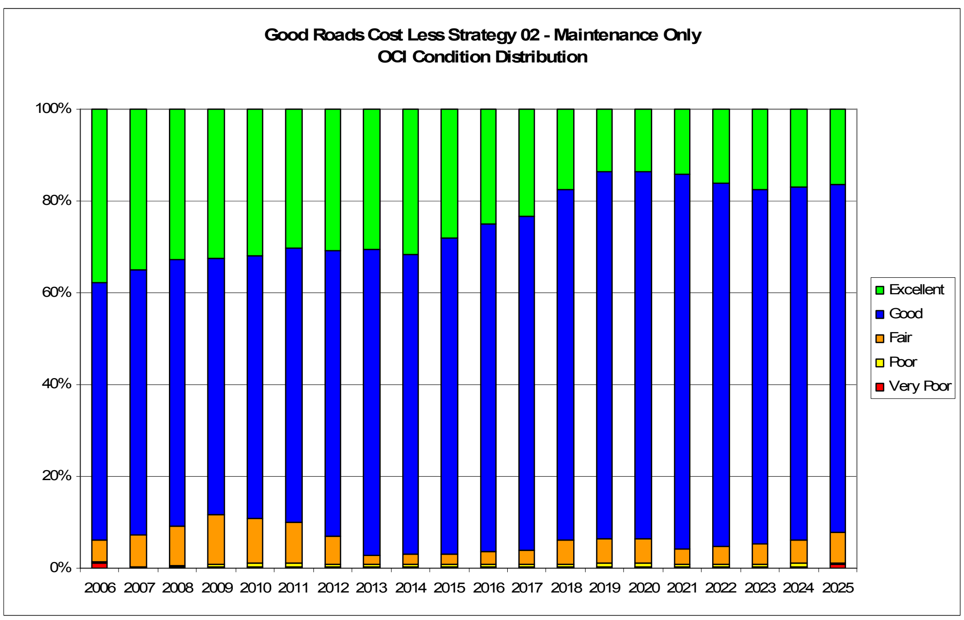


Figure 38: Strategy 02: Maintenance Only OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$13,386,204	$7,150,626,874	$49,003,898	$28,913,788	$116,459,459	$145,373,246
2007	$10,556,930	$7,507,297,753	$34,685,490	$2,490,042	$85,148,052	$87,638,094
2008	$12,283,793	$7,884,650,139	$67,230,578	$9,295,141	$71,660,210	$80,955,351
2009	$12,674,953	$8,269,948,352	$105,279,409	$4,920,272	$123,210,557	$128,130,828
2010	$11,465,638	$8,667,375,244	$205,462,884	$11,481,944	$186,458,000	$197,939,943
2011	$13,810,776	$9,081,158,960	$417,308,386	$6,356,015	$171,906,979	$178,262,995
2012	$9,458,140	$9,496,105,473	$626,234,065	$14,342,966	$200,003,864	$214,346,830
2013	$9,011,100	$9,955,303,108	$430,436,679	$8,820,145	$212,241,647	$221,061,792
2014	$6,572,439	$10,433,946,614	$332,882,587	$14,239,195	$171,922,114	$186,161,309
2015	$6,114,398	$10,963,802,712	$149,355,124	$2,998,312	$96,771,628	$99,769,940
2016	$5,505,323	$11,508,463,270	$299,787,345	$7,779,495	$126,459,466	$134,238,961
2017	$3,929,149	$12,080,396,789	$185,678,367	$6,048,271	$173,015,466	$179,063,737
2018	$3,746,564	$12,693,006,868	$85,524,792	$4,476,300	$157,763,157	$162,239,457
2019	$3,493,026	$13,334,737,569	$967,487,313	$466,008	$134,860,480	$135,326,489
2020	$2,818,693	$13,996,085,661	$1,041,121,522	$4,662,850	$216,022,454	$220,685,304
2021	$3,403,827	$14,670,687,388	$1,238,463,083	$40,668,344	$239,315,244	$279,983,589
2022	$4,338,374	$15,373,330,110	$1,125,591,373	$3,319,261	$285,330,054	$288,649,315
2023	$5,794,142	$16,136,459,133	$484,645,437	$20,832,189	$242,468,381	$263,300,570
2024	$7,832,624	$16,930,389,851	$974,638,756	$12,251,686	$210,412,198	$222,663,884
2025	$9,097,580	$17,709,643,926	$1,190,919,070	$11,500,192	$303,651,995	$315,152,188
Total	**$155,293,674**	**$233,843,415,793**	**$10,011,736,158**	**$215,862,415**	**$3,525,081,407**	**$3,740,943,822**

Table 38: Strategy 02: Maintenance Only Economic Impact Performance Measures

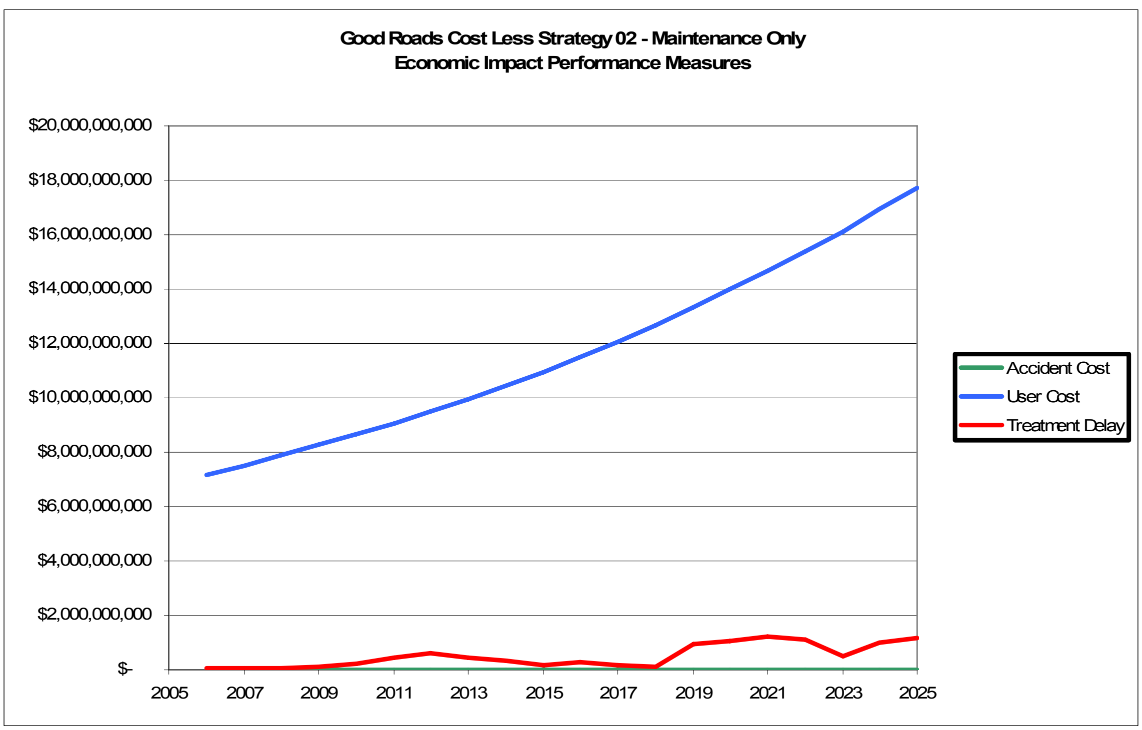


Figure 39: Strategy 02: Maintenance Only Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY (LENGTH = 6,366.636 MI)											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	107.78	477.32	100.92	0	0	0	0	24.47	0	0	**710**
2007	116.84	316.8	17.84	0	0	0	13.11	26.08	0	0	**491**
2008	64.94	295.94	35.71	0	0	0	3.22	22.19	0	0	**422**
2009	157.7	441.7	23.47	0	0	0	15.58	28.13	0	0	**667**
2010	112.38	690.33	29.92	0	0	0	3.76	8.53	0	0	**845**
2011	82.14	643.15	23.06	0	0	0	47.9	22.07	0	0	**818**
2012	262.81	688.53	44.57	0	0	0	46.77	15.64	0	0	**1058**
2013	95.18	858.62	20.19	0	0	0	23.77	13.77	0	0	**1012**
2014	127.39	588.62	40.17	0	0	0	11.06	0.72	0	0	**768**
2015	112.2	292.5	6.56	0	0	0	18.46	0.09	0	0	**430**
2016	88.72	450.42	29.15	0	0	0	3.22	1.78	0	0	**573**
2017	258.42	514.79	15.6	0	0	0	27.27	0	0	0	**816**
2018	36.3	551.52	22.19	0	0	0	0	0	0	0	**610**
2019	95.48	471.89	0.59	0	0	0	29.33	3.4	0	0	**601**
2020	72.28	715.85	8.03	0	0	0	17.33	0	0	0	**813**
2021	35.69	815.46	111.61	0	0	0	28.66	0	0	0	**991**
2022	6.68	889.25	14.3	0	0	0	8.11	18.03	0	0	**936**
2023	0	707.84	64.84	0	0	0	10.55	0	0	0	**783**
2024	27.69	666.6	35.46	0	0	0	0	8.36	0	0	**738**
2025	0	912.93	32.44	0	0	0	3.1	0	0	0	**948**
Total	**1861**	**11990**	**677**	**0**	**0**	**0**	**311**	**193**	**0**	**0**	**15032**

Table 39: Strategy 02: Maintenance Only Treatment Distribution (miles)

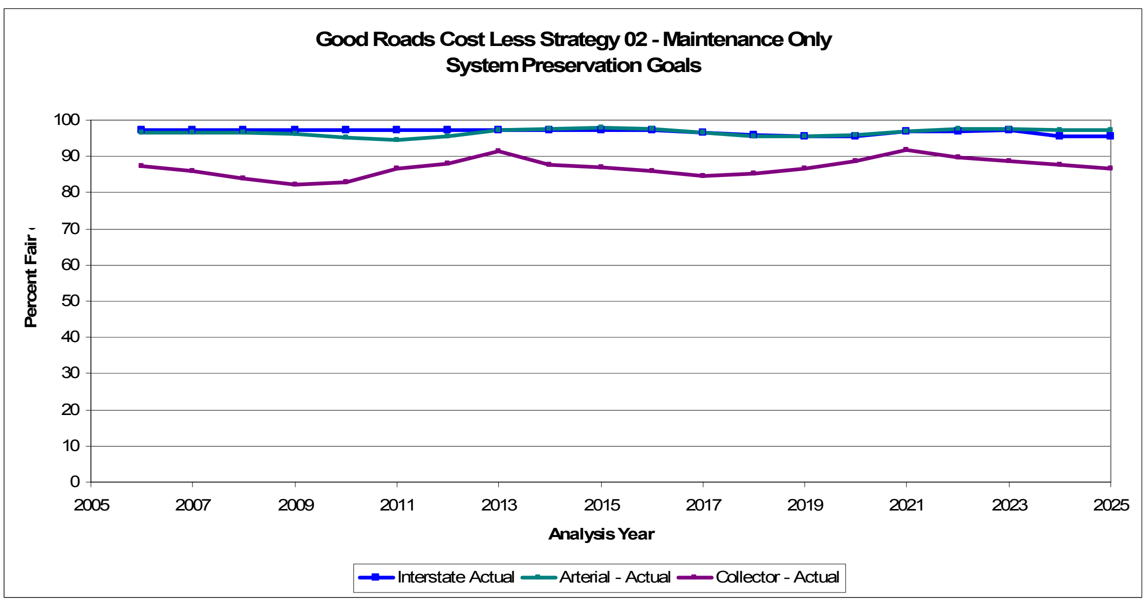


Figure 40: Strategy 02: Maintenance Only System Preservation Goals

5.3.2.2 Discussion

The Maintenance Only strategy attempts to maintain the highway network through a mix of only minor maintenance and preservation treatments. These preservation treatments add no structure to the pavement but attempt to prolong the life of the pavement by replacing and resealing the pavement surface every six to eight years.

At first glance, the Maintenance Only strategy appears to adequately maintain the network, but in reality the maintenance only strategy slows down the deterioration of the network and preserves the pavement surface through minor surface work only but does not improve the structure of the network which can be seen in the deterioration of RSL. Yes, the surface of the pavement is replaced and preserved over the life of the analysis but the entire pavement structure as a whole continues to slowly deteriorate and slowly lose remaining life over the analysis period.

5.3.3 Strategy 03 – Reconstruction Only

5.3.3.1 Results

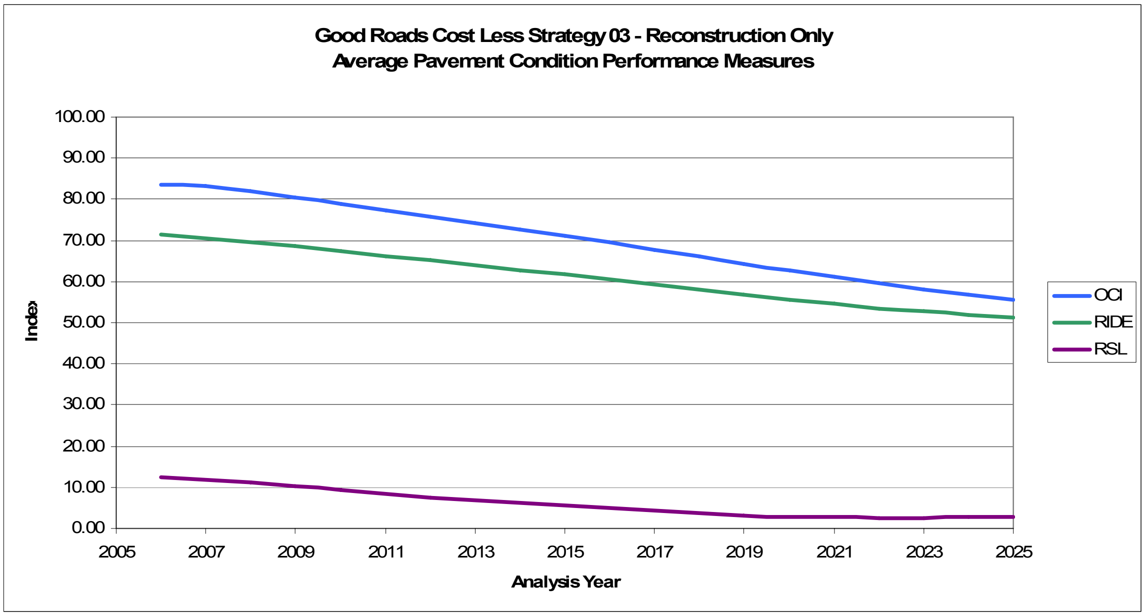


Figure 41: Strategy 03 Reconstruction Only Condition Performance Measures

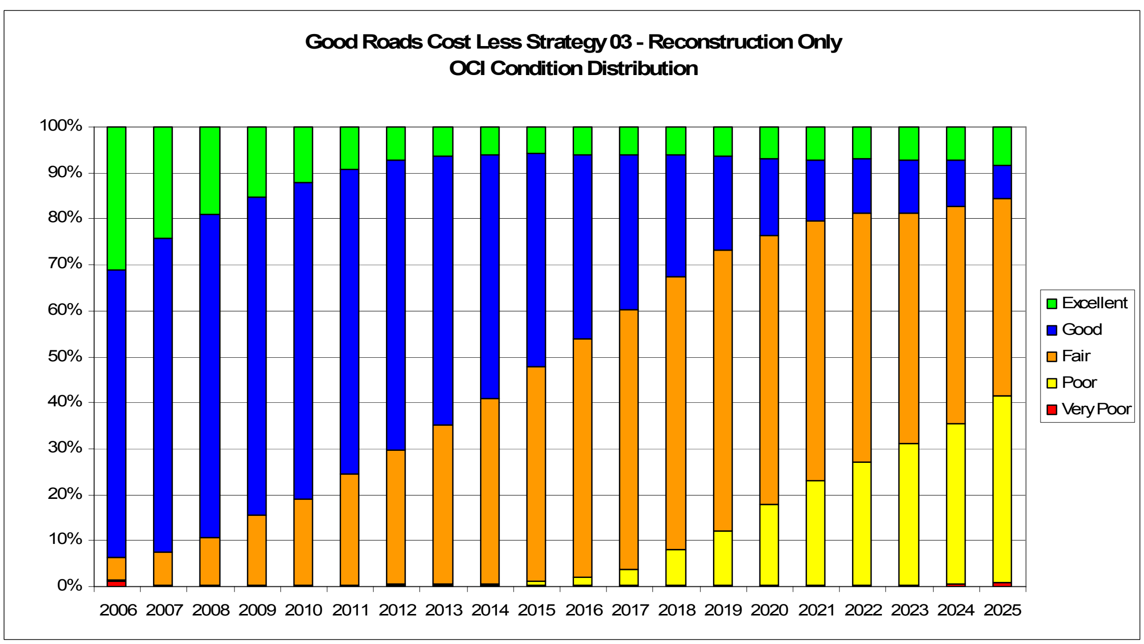


Figure 42: Strategy 03 Reconstruction Only OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$14,024,758	$7,160,239,374	$18,319,681	$178,838,859	$0	$178,838,859
2007	$16,078,087	$7,525,624,024	$48,193,195	$184,165,729	$0	$184,165,729
2008	$19,042,203	$7,915,012,723	$14,955,279	$190,899,596	$0	$190,899,596
2009	$23,502,986	$8,327,397,077	$26,418,153	$131,542,061	$0	$131,542,061
2010	$28,276,104	$8,763,957,851	$2,227,162	$68,427,904	$0	$68,427,904
2011	$36,886,971	$9,222,994,234	$7,304,253	$30,120,976	$0	$30,120,976
2012	$46,254,338	$9,708,011,868	$2,571,552	$29,472,031	$0	$29,472,031
2013	$58,382,562	$10,217,570,119	$4,690,807	$104,621,007	$0	$104,621,007
2014	$77,788,177	$10,742,413,160	$204,703,789	$126,301,657	$0	$126,301,657
2015	$105,302,300	$11,306,101,289	$9,931,471	$86,487,086	$0	$86,487,086
2016	$130,952,886	$11,885,813,012	$660,592,317	$106,576,681	$0	$106,576,681
2017	$165,074,843	$12,512,936,258	$7,981,457	$30,063,255	$0	$30,063,255
2018	$207,873,407	$13,175,683,961	$1,439,259	$20,028,147	$0	$20,028,147
2019	$261,328,229	$13,872,415,471	$5,538,230	$54,142,916	$0	$54,142,916
2020	$323,572,640	$14,598,889,447	$373,871,932	$161,823,211	$0	$161,823,211
2021	$384,737,586	$15,364,876,828	$40,334,068	$160,927,120	$0	$160,927,120
2022	$450,401,747	$16,156,861,195	$410,180,260	$206,509,869	$0	$206,509,869
2023	$505,230,553	$16,974,497,377	$856,902,755	$259,793,536	$0	$259,793,536
2024	$587,269,816	$17,819,114,005	$1,597,244,208	$251,381,076	$0	$251,381,076
2025	$655,923,041	$18,670,980,350	$2,228,456,298	$313,288,687	$0	$313,288,687
Total	**$4,097,903,235**	**$241,921,389,624**	**$6,521,856,126**	**$2,695,411,407**	**$0**	**$2,695,411,407**

Table 40: Strategy 03 Reconstruction Only Economic Impact Performance Measures

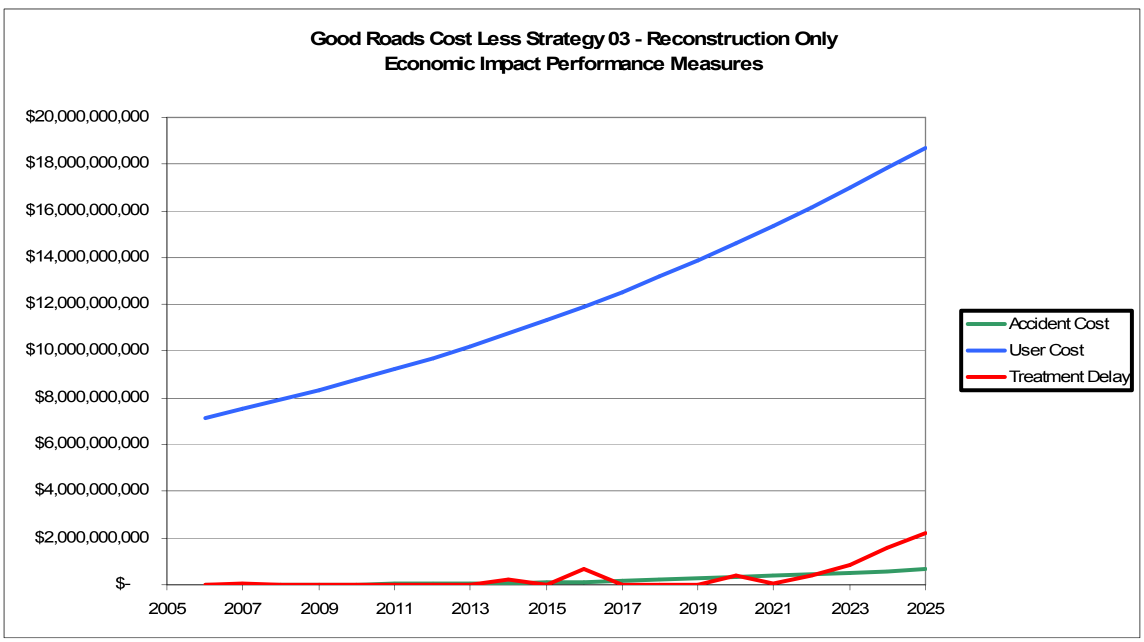


Figure 43: Strategy 03: Reconstruction Only Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY			
Year	Recon Asp	Recon Conc	Total
2006	18	53	**71**
2007	53	7	**60**
2008	61	9	**69**
2009	14	25	**39**
2010	0	15	**15**
2011	9	0	**9**
2012	10	0	**10**
2013	5	20	**25**
2014	27	10	**37**
2015	11	12	**23**
2016	21	13	**34**
2017	9	0	**9**
2018	4	0	**4**
2019	11	8	**18**
2020	30	16	**46**
2021	19	13	**32**
2022	32	10	**42**
2023	66	5	**71**
2024	39	26	**65**
2025	67	23	**90**
Total	**506**	**264**	**771**

Table 41: Strategy 03 Reconstruction Only Treatment Distribution (miles)

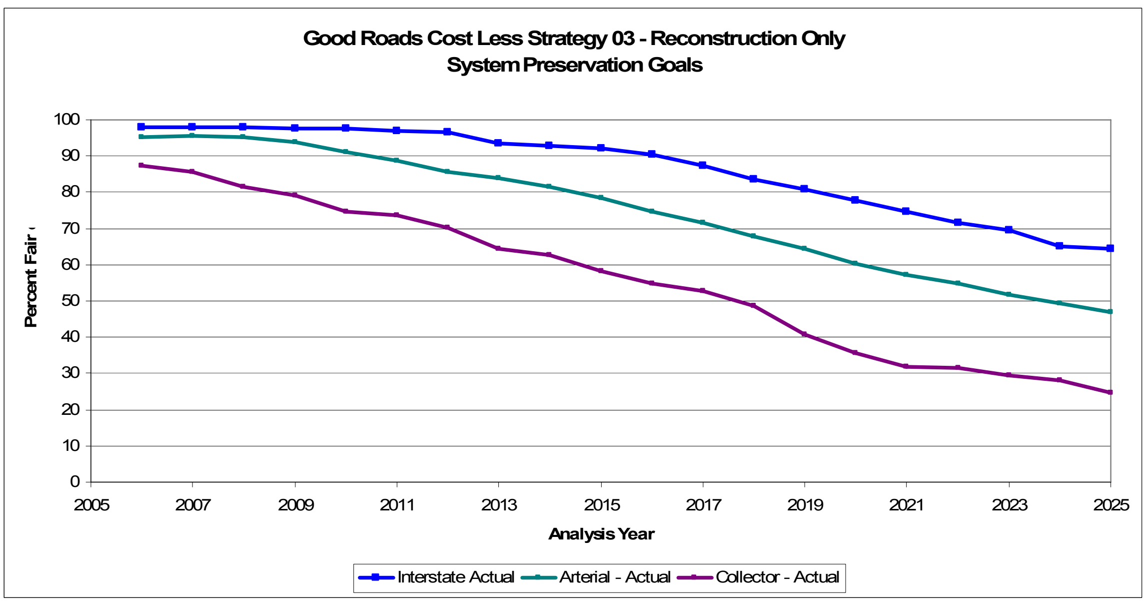


Figure 44: Strategy 03: Reconstruction Only System Preservation Goals

5.3.3.2 Discussion

The Reconstruction only strategy accounts for a "worst first" type of rehabilitation strategy where the pavements are allowed to deteriorate until they reach the poor and very poor categories where they are then programmed for reconstruction. This strategy is the antithesis of the "good roads cost less" philosophy and methodology and attempts to reduce expenditure in the initial period of the analysis so that pavement maintenance and rehabilitation budgets can be used elsewhere within the community.

As witnessed by the results of this analysis, any short term gain by freeing up pavement maintenance and rehabilitation budgets is negated by the tremendous backlog of pavements in fair, poor and very poor condition towards the end of the analysis.

The total expenditure within this strategy is approximately $2.7 Billion compared to expenditures of $4.8 Billion for the UDOT Current Model but the savings in expenditure of $2.1 Billion are quickly offset by increased accident costs of $4.0 Billion and User Cost increases of $10 billion over and above the respective costs within the UDOT Current Model (Strategy 4 which is discussed in the next section).

5.3.4 Strategy 04 – UDOT Current Model – No Budget Categories

5.3.4.1 Results

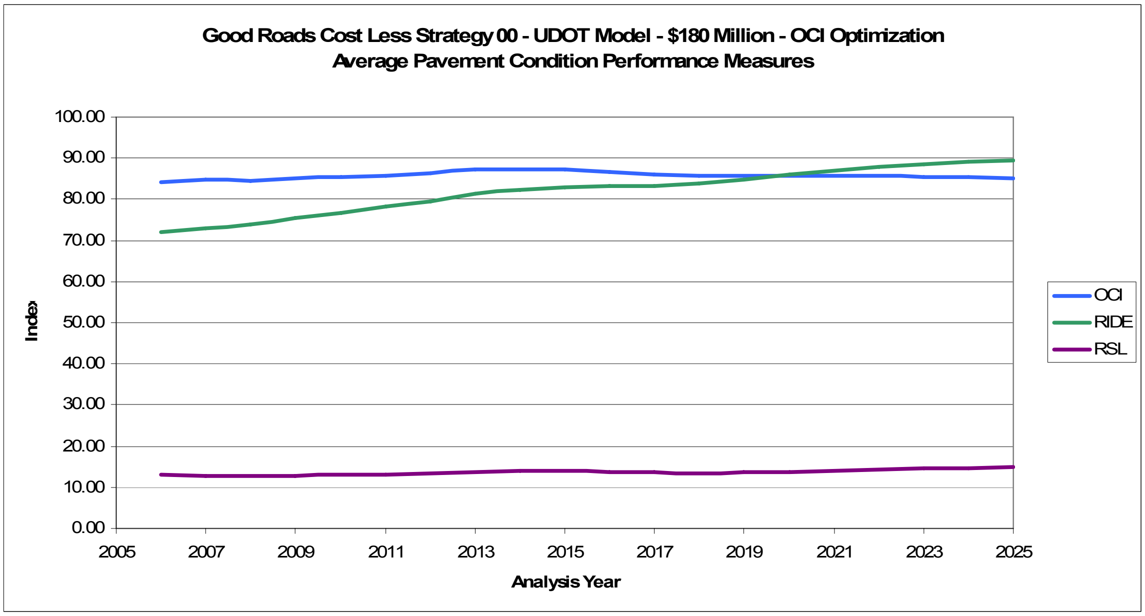


Figure 45: Strategy 04 UDOT Current Model – NBC - Condition Performance Measures

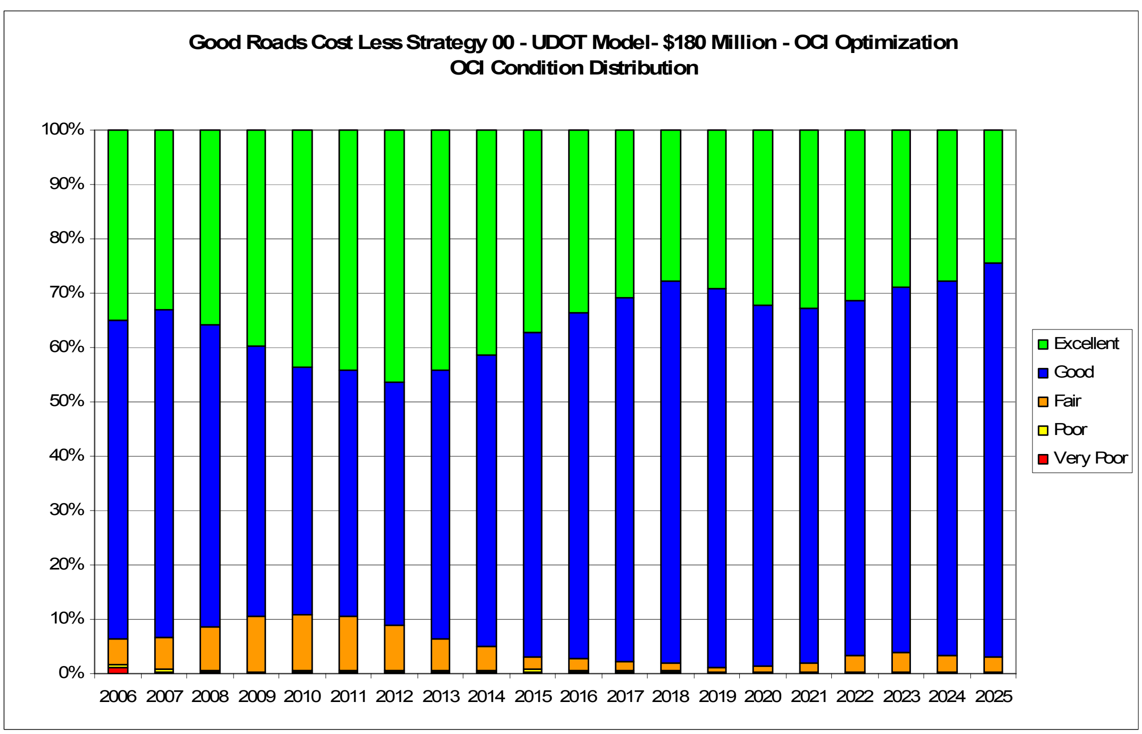


Figure 46: Strategy 04 UDOT Current Model – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$13,469,409	$7,146,536,523	$77,422,023	$165,624,736	$14,189,665	$179,814,401
2007	$10,725,366	$7,492,082,729	$43,678,772	$163,032,726	$22,364,544	$185,397,269
2008	$12,453,085	$7,848,784,942	$330,735,434	$173,842,768	$16,999,322	$190,842,090
2009	$12,348,664	$8,220,163,471	$183,145,878	$161,289,835	$35,318,222	$196,608,057
2010	$11,139,577	$8,606,595,927	$230,667,996	$163,858,637	$38,722,709	$202,581,346
2011	$13,452,876	$9,025,853,823	$200,315,867	$156,647,883	$52,014,171	$208,662,054
2012	$7,647,157	$9,442,783,763	$373,398,612	$148,656,347	$66,172,626	$214,828,973
2013	$4,688,292	$9,895,598,456	$515,741,458	$180,925,496	$40,350,186	$221,275,682
2014	$2,345,042	$10,360,538,305	$648,614,401	$196,463,643	$31,464,426	$227,928,070
2015	$2,839,217	$10,860,566,104	$936,263,277	$184,946,573	$49,877,021	$234,823,595
2016	$3,434,359	$11,397,855,849	$1,031,415,809	$220,310,662	$21,504,944	$241,815,606
2017	$4,304,489	$11,949,977,240	$1,155,406,990	$209,819,708	$39,319,405	$249,139,112
2018	$3,985,427	$12,535,651,469	$2,259,513,397	$242,959,553	$13,537,608	$256,497,162
2019	$3,084,450	$13,166,886,325	$320,929,097	$238,940,724	$25,292,157	$264,232,881
2020	$1,791,382	$13,823,970,669	$1,000,175,685	$245,700,426	$26,460,106	$272,160,532
2021	$2,037,157	$14,475,827,480	$1,440,197,080	$255,146,015	$25,273,522	$280,419,537
2022	$910,945	$15,163,130,579	$2,197,393,115	$276,945,496	$11,855,538	$288,801,035
2023	$1,005,536	$15,885,404,689	$2,613,207,482	$267,478,177	$29,996,252	$297,474,428
2024	$306,156	$16,665,944,347	$2,077,745,558	$297,737,083	$8,630,430	$306,367,514
2025	$335,994	$17,452,798,775	$1,928,928,392	$298,333,631	$17,249,520	$315,583,151
Total	**$112,304,580**	**$231,416,951,466**	**$19,564,896,323**	**$4,248,660,119**	**$586,592,374**	**$4,835,252,494**

Table 42: Strategy 04 UDOT Current Model – NBC Economic Impact Performance Measures

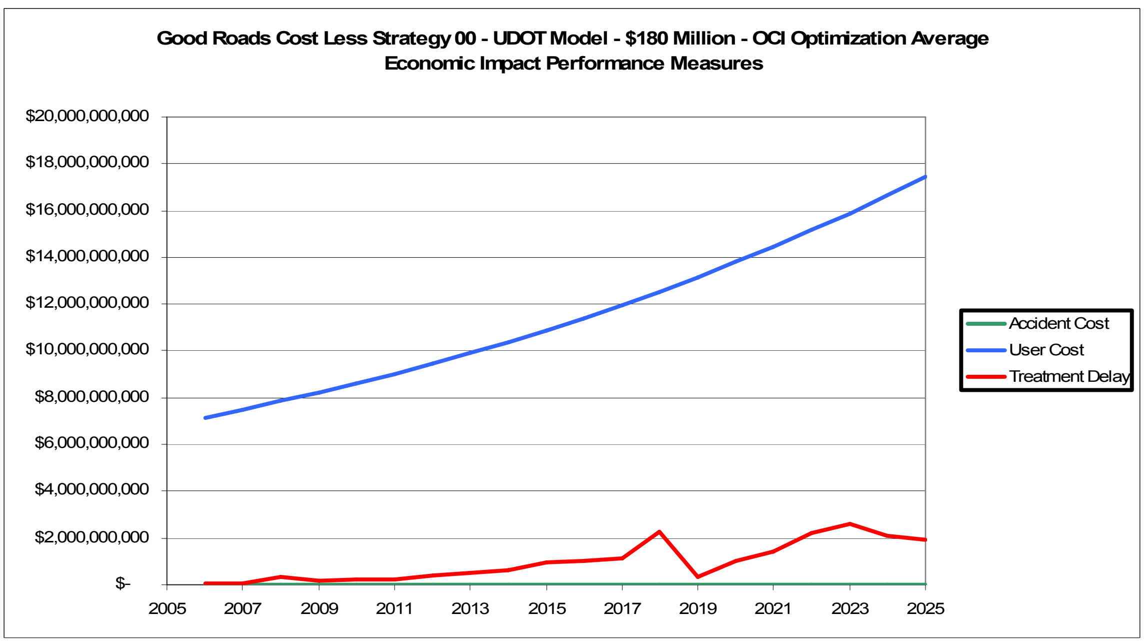


Figure 47: Strategy 04 UDOT Current Model – NBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	103	21	15	0	155	93	4	0	7	32	**430**
2007	119	35	17	8	246	47	6	18	2	25	**524**
2008	76	53	7	0	382	36	10	1	18	2	**584**
2009	149	97	19	28	402	36	12	0	5	1	**749**
2010	191	86	1	4	482	41	4	0	0	0	**811**
2011	138	133	26	13	446	19	35	0	6	0	**816**
2012	337	112	20	9	433	17	41	0	0	0	**969**
2013	149	114	11	25	562	8	21	0	0	0	**889**
2014	191	56	32	52	313	13	20	0	5	7	**689**
2015	297	62	0	91	139	18	15	0	17	0	**638**
2016	264	1	0	11	242	1	23	0	26	12	**580**
2017	402	0	0	17	181	11	31	0	2	22	**666**
2018	117	0	0	50	347	18	10	0	14	6	**560**
2019	270	0	0	25	425	4	25	0	6	11	**766**
2020	294	0	0	15	541	2	11	0	10	0	**873**
2021	194	0	0	0	585	92	23	0	0	0	**893**
2022	95	0	0	5	600	74	11	7	0	2	**794**
2023	65	0	0	6	628	34	18	51	0	0	**803**
2024	57	0	0	44	594	37	13	2	0	0	**747**
2025	50	0	0	51	574	39	26	1	0	0	**741**
Total	**3558**	**771**	**147**	**455**	**8276**	**638**	**358**	**79**	**119**	**121**	**14523**

Table 43: Strategy 04 UDOT Current Model – NBC Treatment Distribution (miles)

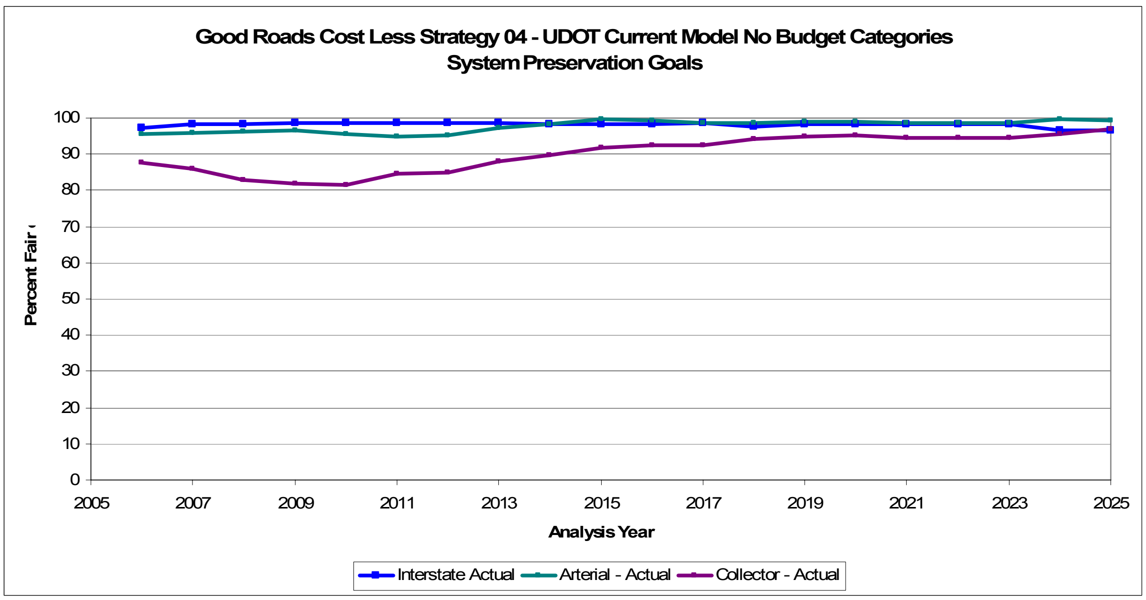


Figure 48: Strategy 04 UDOT Current Model – NBC System Preservation Goals

5.3.4.2 Discussion

This strategy represents the UDOT Current Model for the dTIMS CT Pavement Management System. The model uses treatment timing cycles of 8 years for minor maintenance and preservation treatments and a cycle of at least 10 years for rehabilitation type treatments.

This strategy allows UDOT to maintain the overall condition of the network while stabilizing the condition distribution at more than 90% of the network in excellent or good condition towards the end of the analysis period.

Within this strategy, there are no budget categories which restrict the dollars available to both the minor maintenance treatments and the rehabilitation treatments so dTIMS CT is able to optimize the distribution of funds between the Orange Book (minor maintenance) and the Blue Book (rehabilitation) budget categories as necessary.

Unlike the Maintenance Only strategy, this strategy has a mix of minor maintenance and all of the rehabilitation treatments available. The treatment distribution favors the asphalt minor rehab treatment that not only addresses the pavement surface but also address the pavement structure.

5.3.5 Strategy 04 – UDOT Current Model – With Budget Categories

5.3.5.1 Results

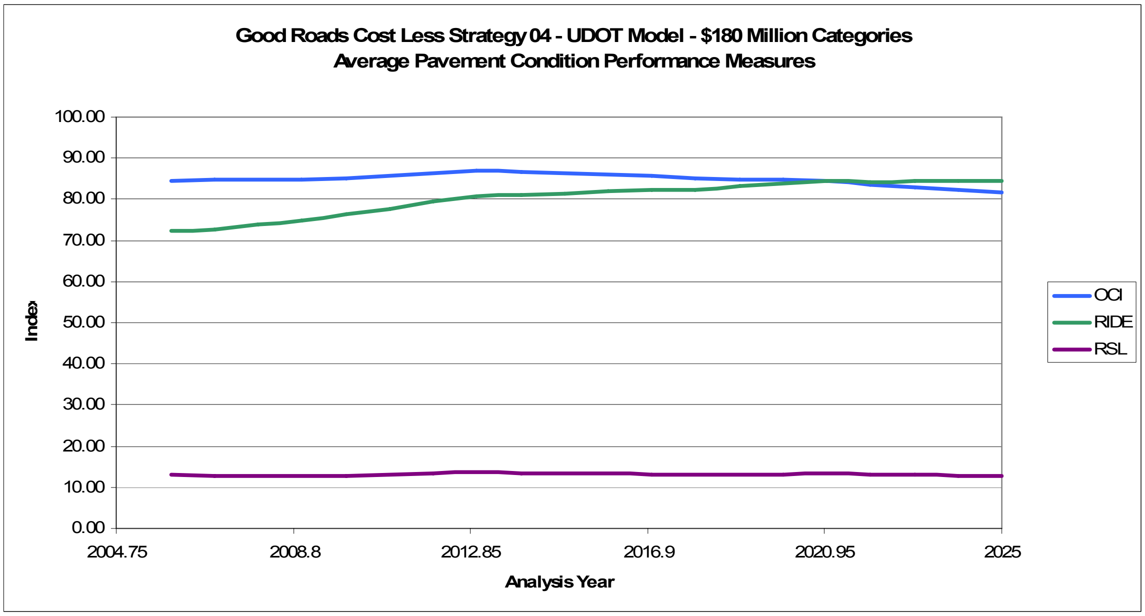


Figure 49: Strategy 04 UDOT Current Model – WBC Condition Performance Measures

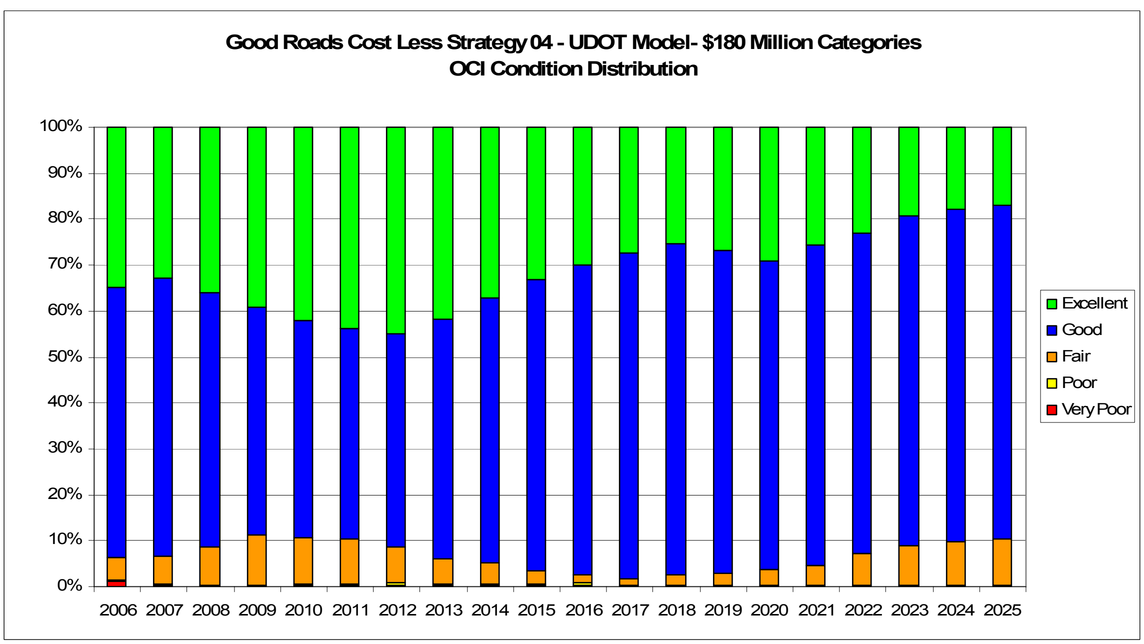


Figure 50: Strategy 04 UDOT Current Model – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$13,469,409	$7,142,491,960	$67,525,498	$119,539,632	$47,013,135	$166,552,767
2007	$11,190,028	$7,492,898,948	$61,312,943	$123,454,827	$34,761,594	$158,216,421
2008	$12,339,482	$7,850,928,066	$318,769,022	$127,187,657	$35,867,014	$163,054,671
2009	$12,182,327	$8,222,246,274	$184,353,560	$131,058,224	$46,480,120	$177,538,344
2010	$11,186,081	$8,608,859,167	$229,745,394	$135,000,340	$67,304,126	$202,304,466
2011	$13,430,524	$9,028,295,489	$195,606,443	$139,094,311	$68,917,630	$208,011,941
2012	$10,769,595	$9,448,149,208	$362,232,654	$143,266,368	$71,486,351	$214,752,719
2013	$3,744,365	$9,899,586,572	$524,965,427	$147,575,741	$73,570,791	$221,146,533
2014	$2,180,315	$10,364,457,234	$647,966,803	$151,996,981	$51,736,301	$203,733,281
2015	$1,639,054	$10,868,017,525	$927,157,295	$156,510,560	$31,170,497	$187,681,057
2016	$1,697,734	$11,413,637,166	$469,423,677	$161,095,151	$27,876,383	$188,971,534
2017	$1,625,068	$11,972,886,317	$1,330,966,159	$166,017,181	$39,462,089	$205,479,270
2018	$1,848,142	$12,556,027,523	$2,454,188,373	$171,061,344	$27,255,185	$198,316,529
2019	$2,061,650	$13,182,127,087	$503,118,226	$176,198,832	$33,921,605	$210,120,436
2020	$1,585,425	$13,837,283,705	$1,018,349,895	$181,507,329	$39,981,046	$221,488,375
2021	$1,940,955	$14,499,798,795	$1,336,381,496	$186,954,356	$27,614,039	$214,568,395
2022	$817,448	$15,191,812,681	$2,419,817,640	$192,557,573	$15,994,112	$208,551,686
2023	$916,214	$15,917,431,467	$2,738,813,206	$198,264,676	$18,664,834	$216,929,510
2024	$222,743	$16,712,515,377	$1,686,372,821	$204,272,417	$9,066,809	$213,339,226
2025	$260,523	$17,511,314,983	$1,815,414,300	$210,418,420	$16,169,972	$226,588,392
Total	**$105,107,082**	**$231,720,765,544**	**$19,292,480,830**	**$3,223,031,920**	**$784,313,635**	**$4,007,345,554**

Table 44: Strategy 04 UDOT Current Model – WBC Economic Impact Performance Measures

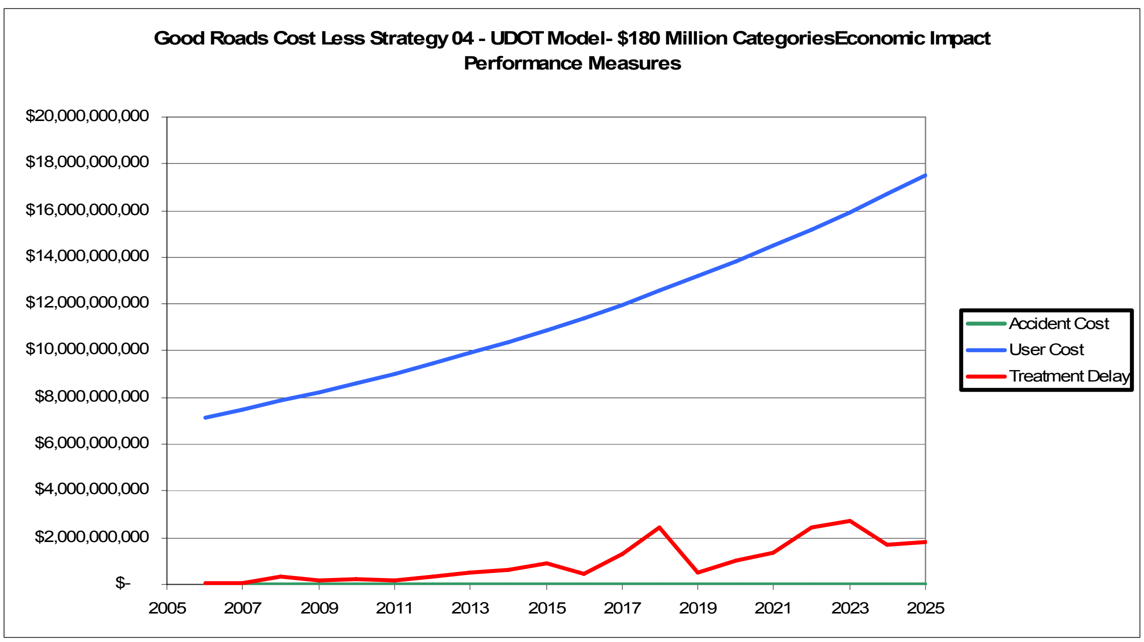


Figure 51: Strategy 04 UDOT Current Model – WBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	101	153	20	0	87	78	4	0	7	25	**475**
2007	125	78	17	0	198	43	6	30	0	20	**517**
2008	85	130	7	12	348	54	10	4	4	0	**653**
2009	149	124	31	9	324	24	14	4	5	3	**686**
2010	181	218	1	4	386	40	4	0	0	0	**835**
2011	158	221	26	14	425	9	35	0	0	0	**888**
2012	336	157	26	15	400	28	33	0	0	0	**995**
2013	115	228	26	14	430	4	28	0	2	0	**849**
2014	184	111	17	1	192	10	29	0	5	13	**560**
2015	268	15	0	49	253	21	11	0	15	0	**632**
2016	333	16	24	21	261	0	18	0	9	7	**689**
2017	369	1	0	43	174	10	26	0	19	0	**641**
2018	270	9	0	8	288	20	11	0	13	0	**618**
2019	383	0	0	0	419	0	25	0	0	5	**831**
2020	433	14	0	24	428	2	16	0	0	0	**916**
2021	201	0	0	0	436	78	26	0	0	0	**741**
2022	15	0	0	0	332	82	14	25	0	2	**470**
2023	64	0	0	10	393	56	19	20	0	0	**561**
2024	36	0	0	4	467	25	12	4	0	0	**549**
2025	80	0	0	7	465	38	21	3	0	0	**614**
Total	**3886**	**1474**	**193**	**235**	**6706**	**622**	**363**	**89**	**79**	**74**	**13721**

Table 45: Strategy 04 UDOT Current Model – WBC Treatment Distribution (miles)

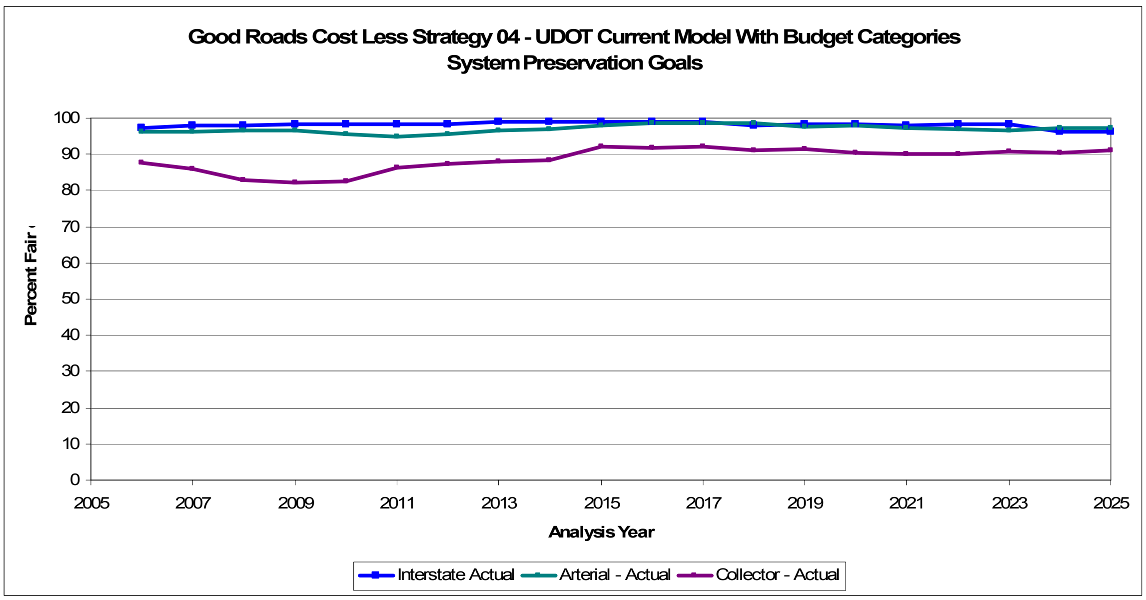


Figure 52: Strategy 04 UDOT Current Model – WBC System Preservation Goals

5.3.5.2 Discussion

This strategy represents the UDOT Current Model for the dTIMS CT Pavement Management System. The model uses treatment timing cycles of 8 years for minor maintenance and preservation treatments and a cycle of at least 10 years for rehabilitation type treatments.

This strategy utilizes budget categories which assigns the distribution of funds between the Orange Book and Blue Book budget categories. During the optimization dTIMS CT has less flexibility in programming projects as dTIMS CT must work within the budgets and the defined budget categories. This lack of flexibility can often lead to large differences between the outcomes of the strategies when nothing else in the model changes except for using budget categories. For example, the total amount of expenditure for this strategy is approximately $800 million less than the previous strategy where the budget category restrictions were removed and the optimization was run wide open.

In terms of overall network condition, the results are similar to the previous strategy with a slight deterioration (approximately 4%) in the condition performance measures and a 2 year reduction in network RSL due to the different expenditures and the restricted optimization.

5.3.6 Strategy 05 – Cycle 6 Years and 10 Years- No Budget Categories

5.3.6.1 Results

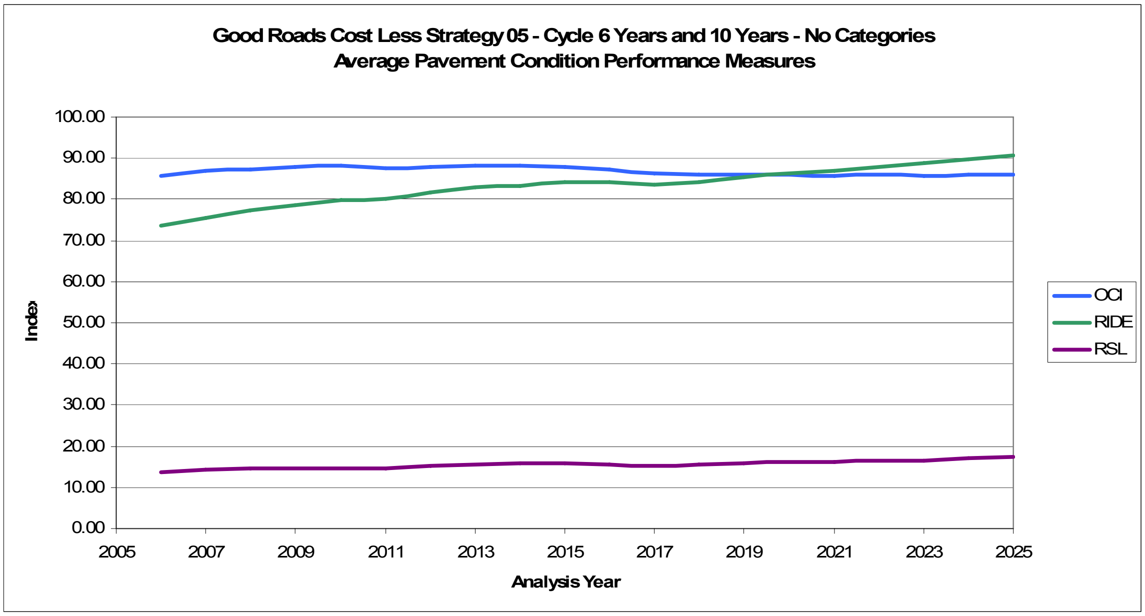


Figure 53: Strategy 05 Cycle 6 Years and 10 Years – NBC Condition Performance Measures

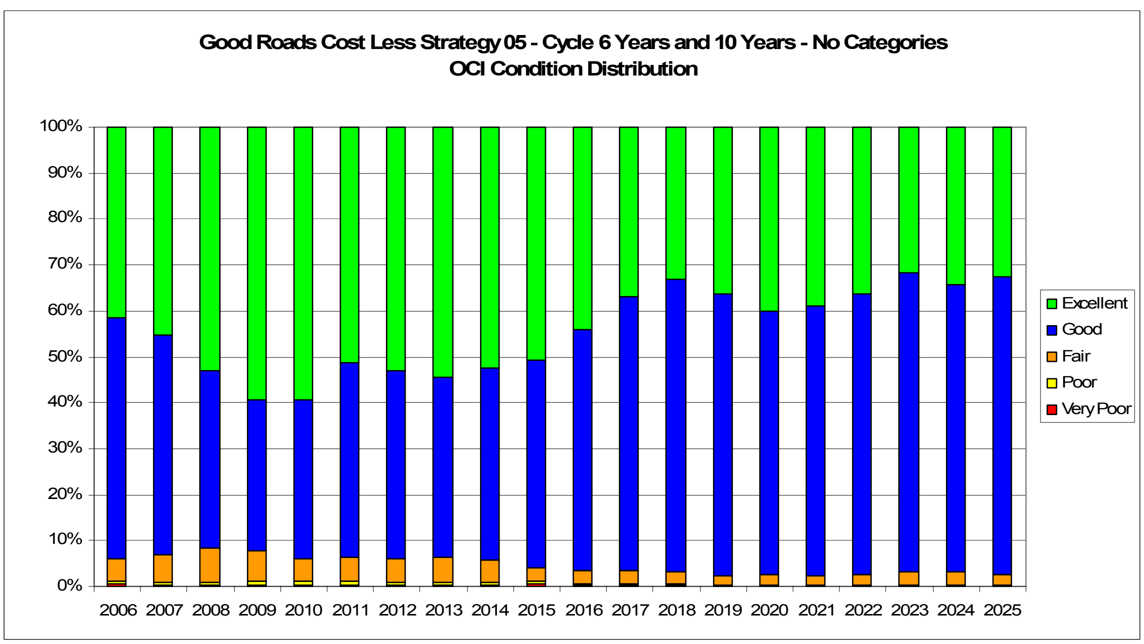


Figure 54: Strategy 05 Cycle 6 Years and 10 Years – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,031,473	$7,105,815,797	$344,883,858	$89,159,204	$90,814,072	$179,973,276
2007	$11,302,106	$7,429,263,511	$180,209,027	$107,137,433	$78,239,722	$185,377,156
2008	$10,328,671	$7,765,438,301	$434,873,011	$119,498,034	$71,450,380	$190,948,414
2009	$10,650,890	$8,126,896,336	$270,642,871	$138,229,302	$58,422,187	$196,651,489
2010	$7,081,915	$8,522,579,261	$367,870,958	$150,223,694	$52,337,037	$202,560,731
2011	$7,522,186	$8,942,918,988	$87,479,359	$197,900,895	$10,631,630	$208,532,525
2012	$7,305,106	$9,367,675,156	$213,809,997	$135,201,038	$79,680,130	$214,881,169
2013	$6,265,210	$9,819,529,254	$207,266,402	$139,429,978	$81,776,669	$221,206,647
2014	$3,390,824	$10,280,204,061	$2,033,038,163	$158,544,297	$69,409,408	$227,953,705
2015	$4,364,490	$10,781,451,651	$915,981,447	$176,752,085	$58,095,120	$234,847,205
2016	$4,185,496	$11,305,017,951	$907,958,637	$211,214,037	$30,565,055	$241,779,091
2017	$6,722,342	$11,860,039,983	$736,378,613	$225,787,298	$23,095,162	$248,882,460
2018	$4,678,029	$12,446,600,285	$819,437,609	$200,687,292	$55,878,039	$256,565,331
2019	$4,848,252	$13,074,282,184	$602,818,029	$211,375,324	$52,871,606	$264,246,930
2020	$4,748,883	$13,744,386,610	$66,169,771	$239,473,845	$32,635,456	$272,109,301
2021	$5,393,671	$14,428,243,994	$624,000,083	$231,485,908	$48,866,849	$280,352,757
2022	$4,699,717	$15,124,416,418	$823,552,121	$253,710,345	$35,121,451	$288,831,796
2023	$5,268,001	$15,825,729,751	$2,297,841,978	$231,048,917	$66,279,591	$297,328,508
2024	$5,889,591	$16,533,790,535	$4,723,838,438	$204,405,392	$102,023,371	$306,428,763
2025	$6,569,056	$17,292,138,600	$4,221,343,300	$234,055,813	$81,538,105	$315,593,918
Total	**$133,245,910**	**$229,776,418,627**	**$20,879,393,671**	**$3,655,320,132**	**$1,179,731,041**	**$4,835,051,173**

Table 46: Strategy 05 Cycle 6 Years and 10 Years – NBC Economic Impact Performance Measures

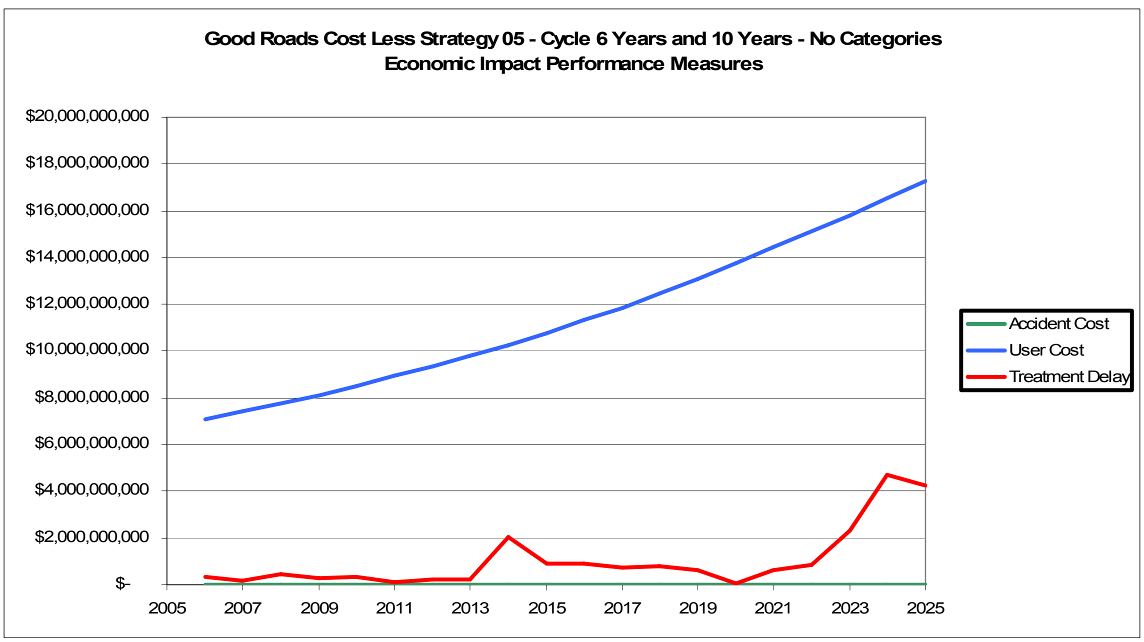


Figure 55: Strategy 05 Cycle 6 Years and 10 Years – NBC Economic Impact Performance

TREATMENT LENGTH SUMMARY (LENGTH = 6,366.636 MI)											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	699	182	19	0	217	115	13	21	4	0	**1269**
2007	582	158	14	1	377	38	42	0	0	0	**1212**
2008	236	205	30	3	401	41	38	0	0	0	**954**
2009	137	213	16	3	418	30	14	0	0	0	**830**
2010	33	190	20	4	415	28	43	0	3	1	**736**
2011	18	26	15	21	151	39	9	0	0	44	**322**
2012	927	39	6	20	317	56	21	5	0	0	**1391**
2013	972	3	11	8	211	12	84	0	0	15	**1316**
2014	672	10	0	22	127	16	61	6	21	8	**943**
2015	454	0	0	86	113	3	51	20	27	0	**753**
2016	176	0	0	30	50	73	30	21	42	0	**422**
2017	52	0	0	14	75	47	28	44	3	34	**297**
2018	524	0	0	41	150	72	23	25	21	0	**857**
2019	479	0	0	113	232	28	50	21	5	0	**926**
2020	389	0	0	83	351	20	9	0	11	0	**863**
2021	372	0	0	73	228	18	41	13	4	11	**760**
2022	139	0	0	0	608	33	33	19	0	2	**835**
2023	31	0	0	3	572	0	43	90	0	0	**739**
2024	427	0	0	0	515	37	39	169	0	0	**1187**
2025	318	0	0	27	475	20	61	78	0	0	**978**
Total	**7636**	**1024**	**130**	**552**	**6002**	**723**	**733**	**532**	**143**	**115**	**17591**

Table 47: Strategy 05 Cycle 6 Years and 10 Years – NBC Treatment Distribution (miles)

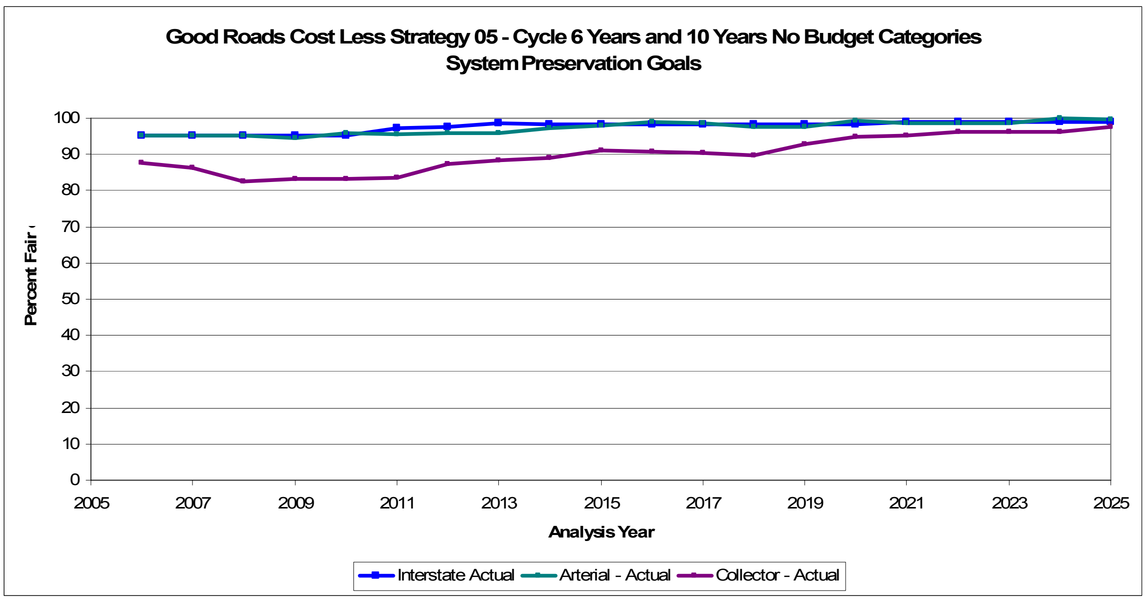


Figure 56: Strategy 05 Cycle 6 Years and 10 Years – NBC Economic System Preservation Goals

5.3.6.2 *Discussion*

This strategy shortens the time cycle between successive minor maintenance treatments to 6 years and fixes the timing cycle for all major rehabilitation treatments to 10 years.

This strategy programs more miles of pavement maintenance and rehabilitation than any other strategy and improves the network condition to the highest levels of all of the alternative strategies in the study. Delay costs and accident costs are higher than the current model but user costs are reduced.

It is worthy to note that the chip seal treatment is used more than any other treatment within this strategy as it is the preferred seal treatment for most highway sections and it has the shortest cycle.

5.3.7 Strategy 05 – Cycle 6 Years and 10 Years- With Budget Categories

5.3.7.1 Results

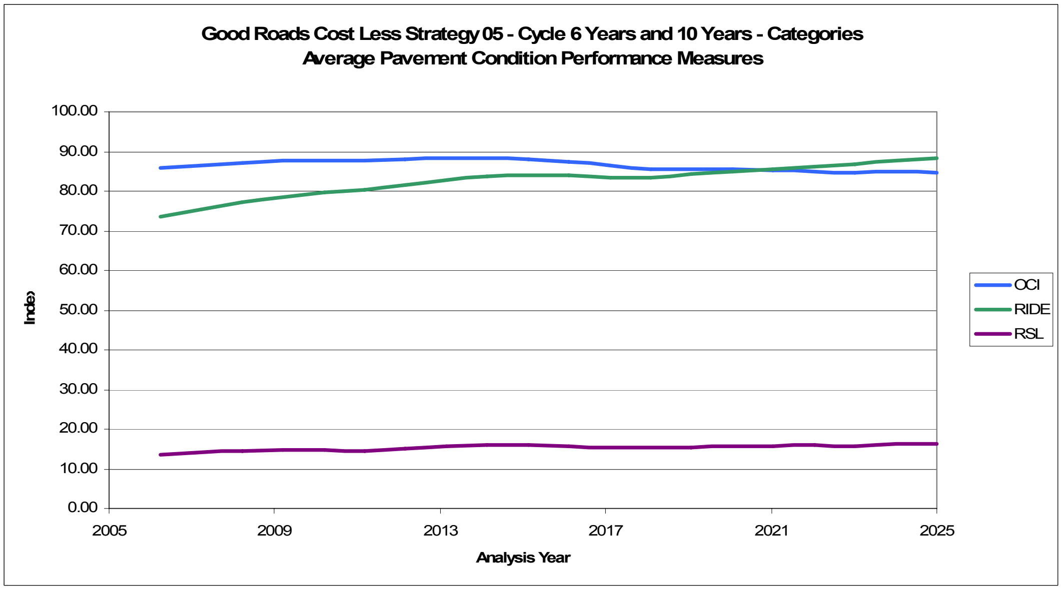


Figure 57: Strategy 05 Cycle 6 Years and 10 Years – WBC Condition Performance Measures

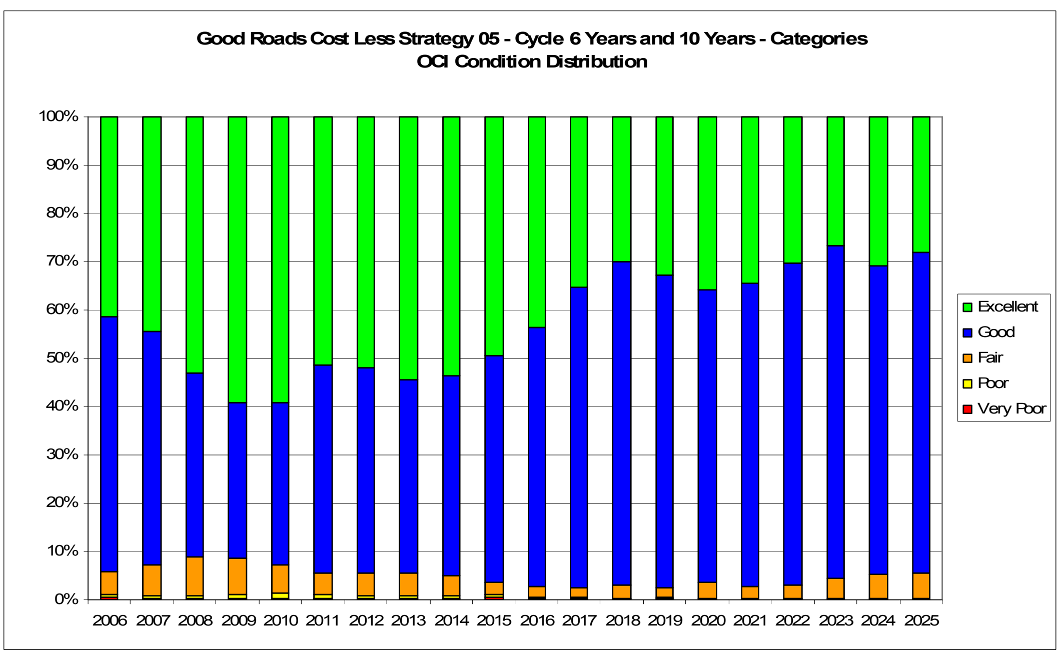


Figure 58: Strategy 05 Cycle 6 Years and 10 Years – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,532,681	$7,108,057,260	$343,363,714	$119,994,633	$59,918,694	$179,913,327
2007	$11,810,132	$7,428,003,495	$197,827,291	$123,575,915	$61,756,675	$185,332,590
2008	$11,058,495	$7,764,775,595	$449,124,652	$127,237,353	$63,632,565	$190,869,918
2009	$11,946,606	$8,123,794,078	$303,632,097	$131,116,484	$65,541,217	$196,657,702
2010	$11,263,734	$8,520,347,220	$356,746,955	$135,049,892	$67,518,872	$202,568,763
2011	$13,568,363	$8,944,345,613	$51,322,078	$139,106,484	$69,472,630	$208,579,114
2012	$12,174,662	$9,366,579,109	$222,425,986	$143,177,105	$71,610,962	$214,788,066
2013	$11,806,197	$9,822,059,989	$151,929,550	$147,528,617	$73,460,855	$220,989,472
2014	$9,031,709	$10,287,625,730	$1,925,958,903	$151,855,000	$75,904,407	$227,759,407
2015	$3,954,084	$10,779,173,424	$1,142,414,191	$156,434,025	$77,703,603	$234,137,628
2016	$3,502,426	$11,302,773,067	$995,164,910	$161,065,660	$36,969,868	$198,035,528
2017	$5,821,513	$11,867,875,361	$371,171,205	$166,069,979	$41,322,205	$207,392,184
2018	$5,404,026	$12,449,469,997	$1,027,171,467	$170,867,447	$48,615,075	$219,482,521
2019	$4,832,470	$13,070,432,528	$566,759,603	$176,222,304	$63,397,962	$239,620,265
2020	$4,448,369	$13,740,477,944	$79,170,681	$181,501,338	$38,302,745	$219,804,083
2021	$5,196,125	$14,425,367,088	$633,567,171	$186,754,237	$52,127,555	$238,881,793
2022	$4,482,570	$15,125,068,760	$981,079,598	$192,482,850	$44,361,374	$236,844,224
2023	$5,029,580	$15,835,464,408	$2,279,466,544	$198,294,470	$66,799,171	$265,093,642
2024	$5,628,088	$16,559,564,369	$3,414,701,399	$204,233,438	$100,134,447	$304,367,885
2025	$6,282,519	$17,313,143,979	$5,191,494,202	$210,378,869	$73,453,406	$283,832,275
Total	**$159,774,349**	**$229,834,399,013**	**$20,684,492,197**	**$3,222,946,099**	**$1,252,004,288**	**$4,474,950,387**

Table 48: Strategy 05 Cycle 6 Years and 10 Years – WBC Economic Impact Performance

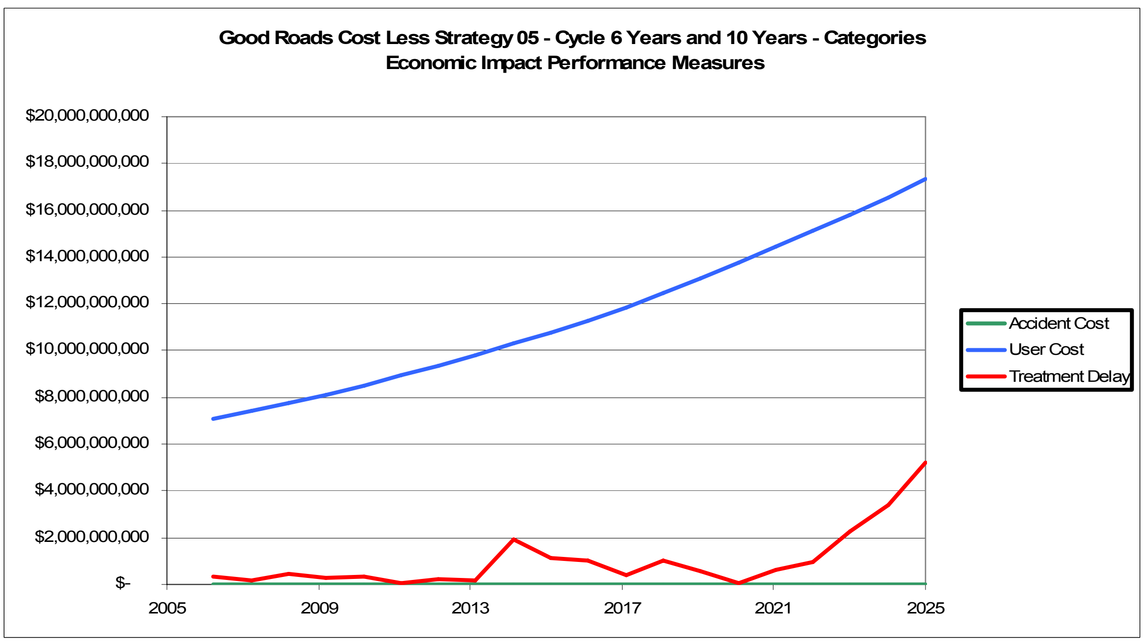


Figure 59: Strategy 05 Cycle 6 Years and 10 Years – WBC Economic Impact Performance

TREATMENT LENGTH SUMMARY (LENGTH = 6,366.636 MI)											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	598	87	31	1	300	127	4	13	4	0	**1165**
2007	606	87	20	2	386	84	29	4	0	0	**1218**
2008	350	152	13	3	438	13	38	0	0	0	**1007**
2009	180	191	15	1	411	13	35	0	0	0	**847**
2010	11	256	35	3	338	24	29	0	0	7	**702**
2011	7	273	0	2	128	35	28	0	3	32	**509**
2012	852	55	6	34	216	63	3	13	0	7	**1248**
2013	1003	1	11	19	239	13	48	0	0	15	**1348**
2014	766	26	0	23	127	16	66	6	20	7	**1057**
2015	503	16	0	59	63	3	86	13	29	1	**773**
2016	256	4	0	18	67	59	18	28	34	0	**485**
2017	99	1	0	4	56	78	42	57	7	24	**368**
2018	483	0	0	9	83	27	13	29	15	10	**670**
2019	583	0	0	63	218	45	38	40	4	0	**990**
2020	499	0	0	35	340	20	8	0	5	0	**908**
2021	373	0	0	98	253	12	46	13	0	0	**795**
2022	169	0	0	0	461	40	45	23	0	2	**741**
2023	60	0	0	0	477	0	38	90	0	0	**665**
2024	308	0	0	3	552	6	41	181	0	0	**1092**
2025	277	0	0	0	454	24	48	89	0	0	**892**
Total	**7984**	**1149**	**130**	**380**	**5608**	**703**	**701**	**600**	**120**	**103**	**17479**

Table 49: Strategy 05 Cycle 6 Years and 10 Years – WBC Treatment Distribution (miles)

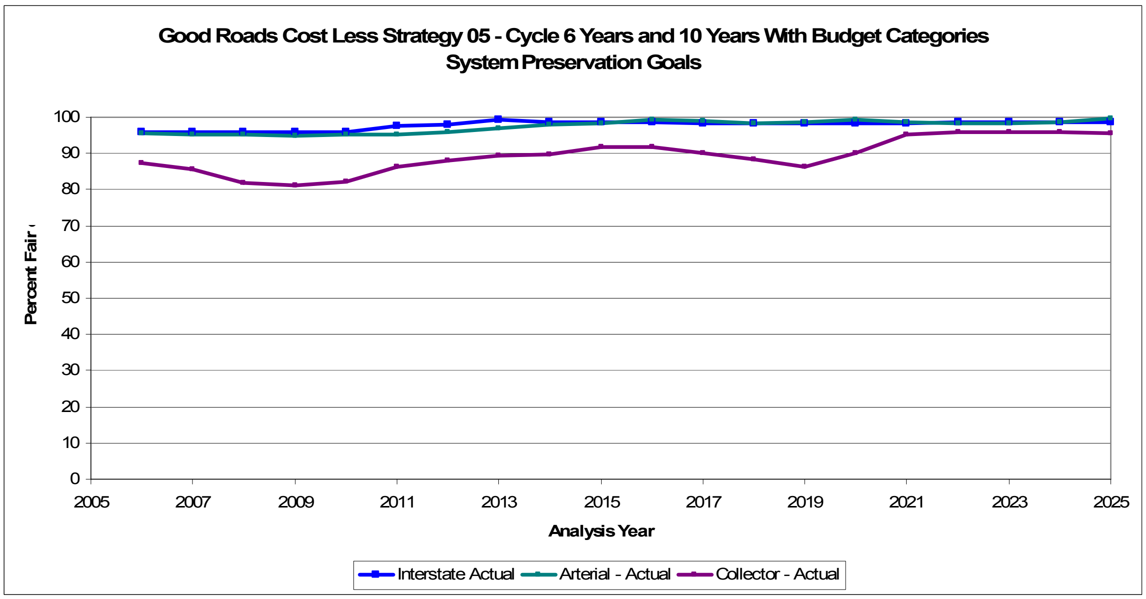


Figure 60: Strategy 05 Cycle 6 Years and 10 Years – WBC System Preservation Goals

5.3.7.2 Discussion

This strategy like the previous strategy shortens the time cycle between successive minor maintenance treatments to 6 years and fixes the timing cycle for all major rehabilitation treatments to 10 years.

This strategy utilizes the Orange Book and Blue budget categories that restrict the funding within each category so the results are not quite as good as the previous strategy without budget categories, but the results are quite similar.

5.3.8 Strategy 06 – Cycle 6 Years and 12 Years- No Budget Categories

5.3.8.1 Results

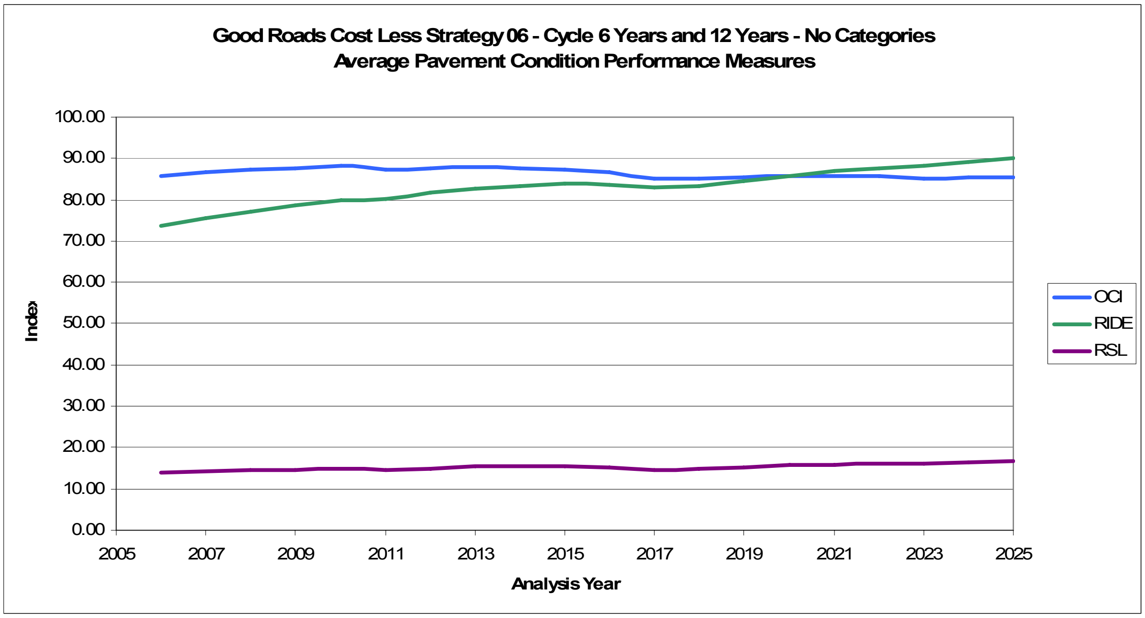


Figure 61: Strategy 06 Cycle 6 Years and 12 Years – NBC Condition Performance Measures

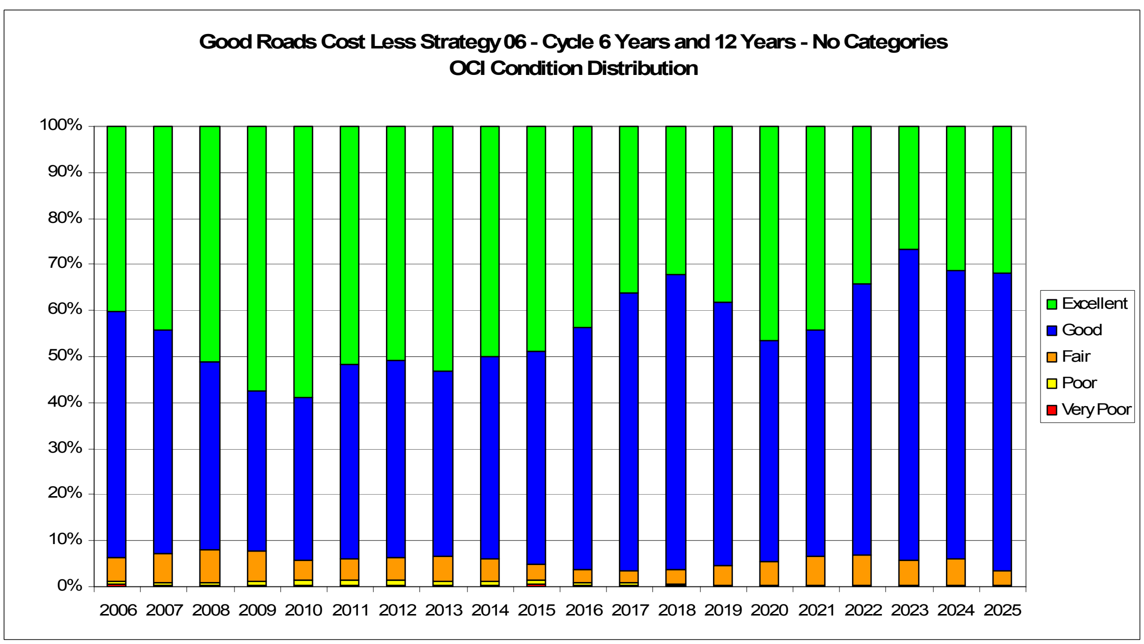


Figure 62: Strategy 06 Cycle 6 Years and 12 Years – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,095,280	$7,102,923,052	$373,682,014	$91,239,948	$88,710,288	$179,950,236
2007	$11,313,910	$7,422,531,184	$319,539,495	$105,192,112	$80,188,590	$185,380,701
2008	$8,353,123	$7,767,653,835	$252,157,674	$120,533,349	$70,420,667	$190,954,015
2009	$8,191,471	$8,131,112,242	$261,766,156	$154,938,906	$41,731,377	$196,670,283
2010	$4,849,274	$8,527,785,913	$361,041,708	$155,523,790	$47,037,227	$202,561,017
2011	$5,029,398	$8,945,443,369	$133,264,571	$193,681,268	$14,935,371	$208,616,639
2012	$5,210,399	$9,369,237,965	$170,381,127	$138,567,551	$76,166,319	$214,733,870
2013	$4,234,359	$9,821,513,042	$310,946,470	$136,979,175	$84,381,770	$221,360,945
2014	$3,915,771	$10,286,844,793	$1,855,887,170	$183,381,910	$44,344,206	$227,726,116
2015	$5,117,555	$10,790,379,235	$868,703,146	$176,405,181	$58,265,384	$234,670,565
2016	$4,773,541	$11,327,414,761	$697,085,816	$204,473,732	$37,349,385	$241,823,117
2017	$5,600,303	$11,897,486,991	$431,593,130	$224,004,751	$25,100,058	$249,104,809
2018	$4,678,029	$12,468,608,596	$750,086,909	$178,132,307	$78,157,800	$256,290,107
2019	$4,848,252	$13,079,099,220	$1,190,898,372	$191,059,905	$72,441,496	$263,501,401
2020	$4,627,866	$13,722,464,011	$706,008,712	$220,494,117	$51,549,912	$272,044,029
2021	$5,713,640	$14,397,161,175	$760,506,146	$216,089,735	$63,878,827	$279,968,562
2022	$4,699,717	$15,122,799,281	$533,962,420	$249,970,663	$38,566,369	$288,537,032
2023	$5,268,001	$15,872,407,592	$1,806,485,764	$240,647,442	$56,784,604	$297,432,046
2024	$5,889,591	$16,590,997,163	$1,363,783,372	$185,966,694	$120,468,230	$306,434,925
2025	$6,569,056	$17,324,673,249	$5,548,557,151	$238,412,549	$77,191,670	$315,604,219
Total	**$120,978,536**	**$229,968,536,668**	**$18,696,337,324**	**$3,605,695,084**	**$1,227,669,550**	**$4,833,364,634**

Table 50: Strategy 06 Cycle 6 Years and 12 Years – NBC Economic Impact Performance

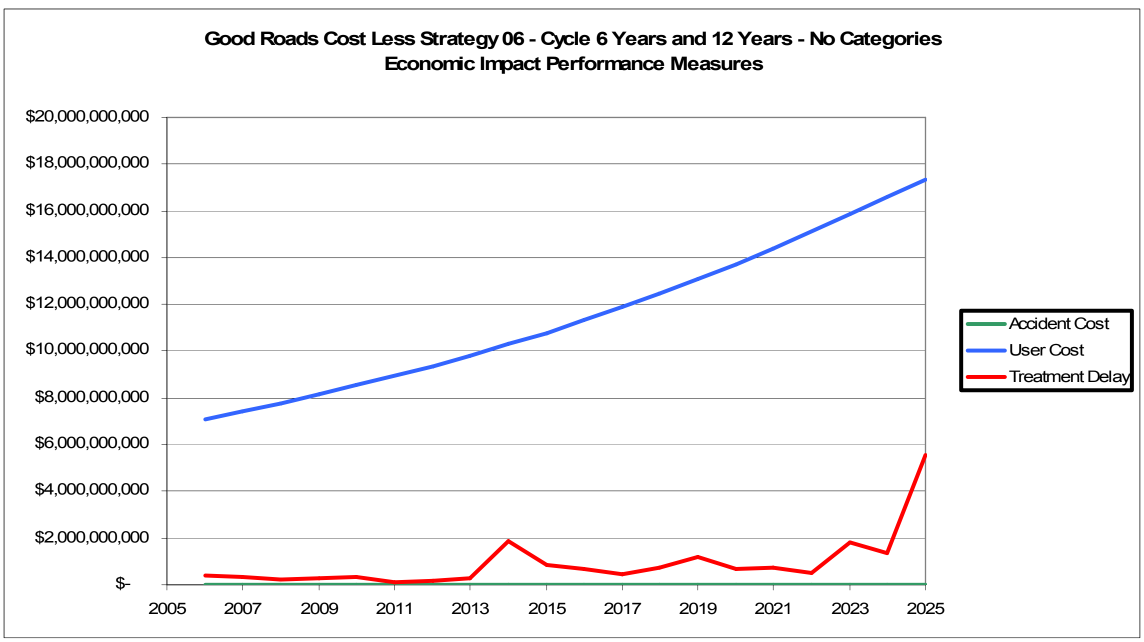


Figure 63: Strategy 06 Cycle 6 Years and 12 Years – NBC Economic Impact Performance

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	643	196	17	0	185	175	15	13	4	0	**1248**
2007	556	162	12	1	381	28	41	4	0	0	**1186**
2008	226	190	2	4	422	27	45	0	0	0	**916**
2009	134	131	6	5	486	42	13	0	0	0	**816**
2010	0	167	6	7	493	24	37	0	2	1	**736**
2011	7	27	29	10	121	52	20	0	2	41	**309**
2012	841	38	6	35	263	52	27	14	0	3	**1279**
2013	896	30	11	4	240	3	86	0	0	15	**1286**
2014	433	0	0	31	177	16	45	6	20	8	**735**
2015	262	7	0	85	96	3	47	34	29	0	**563**
2016	185	0	0	34	37	4	34	40	37	12	**383**
2017	43	0	0	15	0	0	19	44	25	22	**168**
2018	635	0	0	36	52	122	41	53	23	0	**963**
2019	686	0	0	98	166	44	66	7	5	0	**1072**
2020	650	0	0	77	329	5	16	0	10	0	**1087**
2021	445	0	0	61	320	0	60	13	0	11	**911**
2022	155	0	0	137	252	12	35	20	4	2	**616**
2023	34	0	0	135	216	35	30	57	0	0	**506**
2024	450	0	0	13	375	49	51	226	0	0	**1164**
2025	303	0	0	45	443	9	65	60	0	0	**924**
Total	**7583**	**949**	**89**	**833**	**5053**	**701**	**794**	**590**	**161**	**115**	**16867**

Table 51: Strategy 06 Cycle 6 Years and 12 Years – NBC Treatment Distribution (miles)

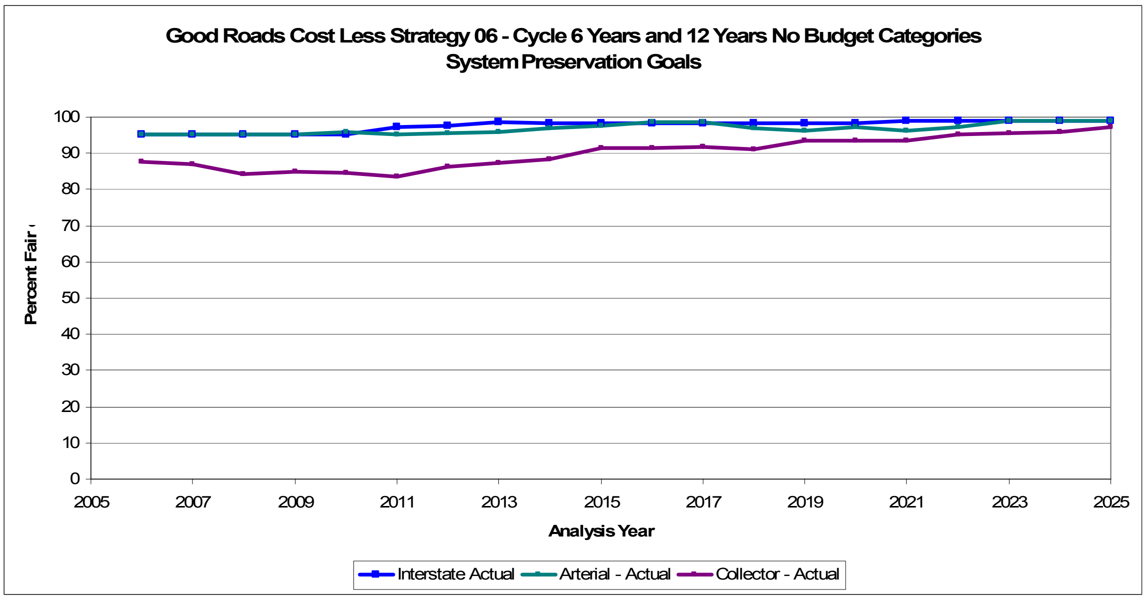


Figure 64: Strategy 06 Cycle 6 Years and 12 Years – NBC System Preservation Goals

5.3.8.2 Discussion

This strategy shortens the time cycle between successive minor maintenance treatments to 6 years and fixes the timing cycle for all major rehabilitation treatments to 12 years.

The results of this strategy are similar enough to the results of the previous strategy to suggest that a cycle of 6 years and 12 years is not much different than that of a 6 year and 10 year cycle. One noticeable difference though is that the treatment delay costs are slightly lower $18 Billion versus $20 Billion as the number of rehabilitation treatments is reduced due to the longer timing cycle.

5.3.9 Strategy 06 – Cycle 6 Years and 12 Years-With Budget Categories

5.3.9.1 Results

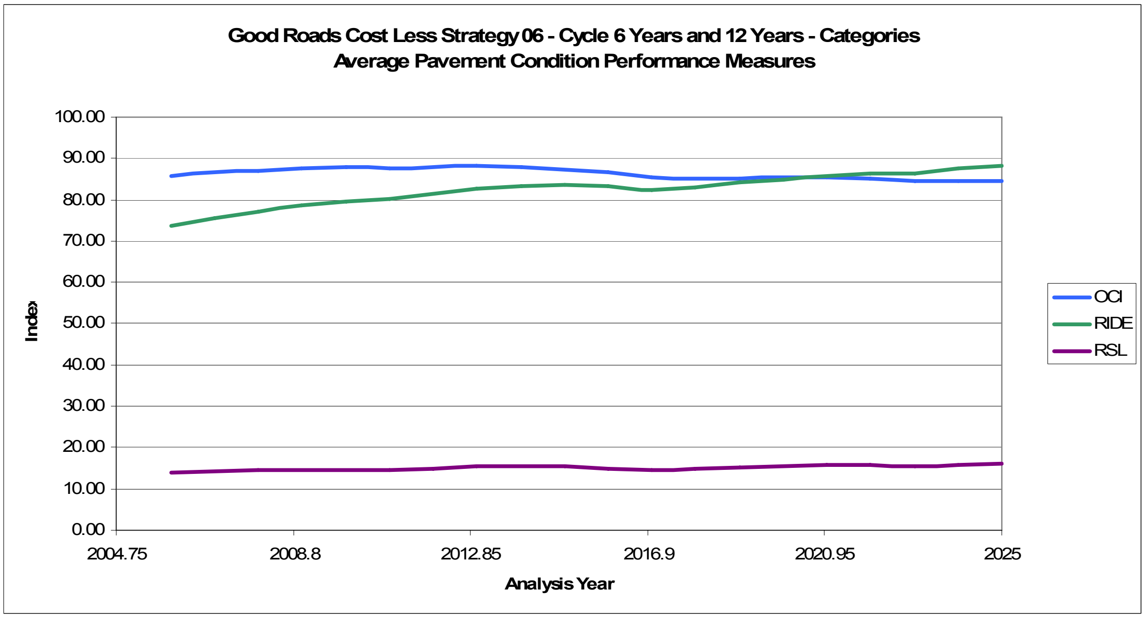


Figure 65: Strategy 06 Cycle 6 Years and 12 Years – WBC Condition Performance Measures

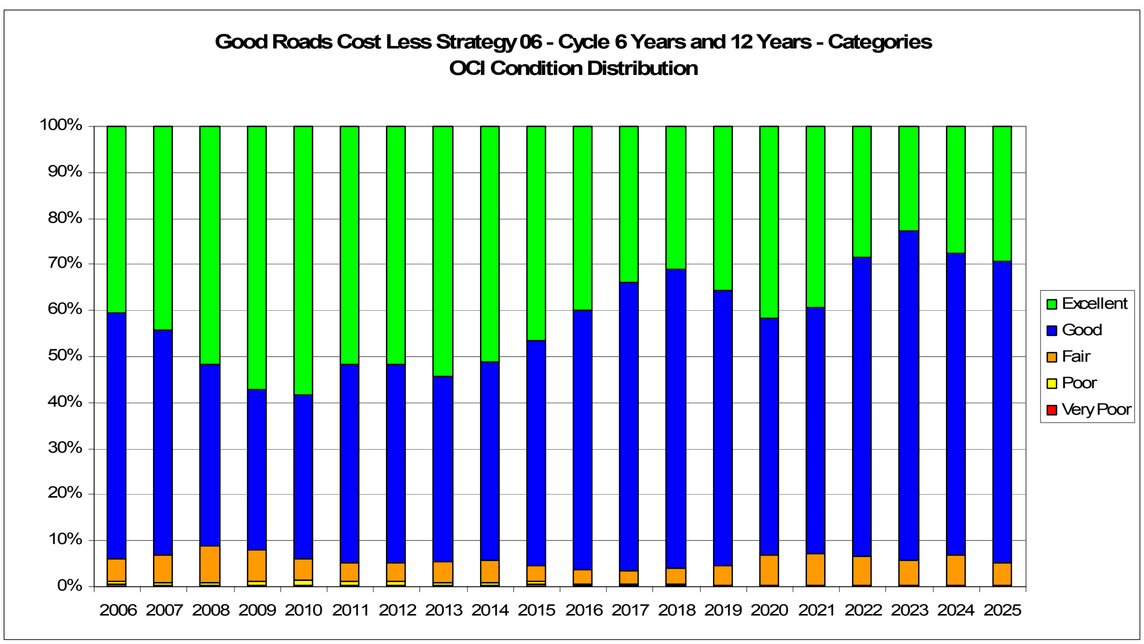


Figure 66: Strategy 06 Cycle 6 Years and 12 Years – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,797,805	$7,106,949,745	$333,055,920	$119,993,018	$59,911,100	$179,904,118
2007	$11,482,549	$7,425,941,802	$270,756,082	$123,593,137	$61,703,499	$185,296,637
2008	$9,282,555	$7,765,929,599	$330,092,674	$127,247,024	$63,614,610	$190,861,634
2009	$10,634,019	$8,127,551,296	$332,255,219	$130,902,084	$65,525,642	$196,427,727
2010	$5,059,772	$8,525,723,139	$344,200,036	$135,056,175	$67,317,303	$202,373,478
2011	$4,958,239	$8,941,620,190	$115,647,994	$139,012,682	$69,429,387	$208,442,069
2012	$3,975,630	$9,370,711,663	$153,995,451	$143,244,418	$71,583,129	$214,827,548
2013	$3,680,390	$9,823,735,481	$177,447,787	$147,464,988	$73,642,293	$221,107,282
2014	$3,589,905	$10,289,285,188	$1,954,871,085	$151,971,409	$75,638,746	$227,610,155
2015	$4,436,458	$10,797,960,627	$839,628,325	$156,352,587	$53,647,783	$210,000,370
2016	$3,743,096	$11,332,738,399	$715,628,334	$161,063,311	$36,569,530	$197,632,841
2017	$4,976,281	$11,908,202,274	$297,071,965	$166,074,922	$49,522,663	$215,597,585
2018	$5,591,048	$12,477,202,614	$711,119,935	$170,790,789	$63,924,785	$234,715,573
2019	$5,117,170	$13,084,859,543	$1,278,581,282	$176,028,511	$79,006,568	$255,035,079
2020	$5,051,510	$13,728,122,812	$1,234,923,137	$181,315,131	$63,804,143	$245,119,275
2021	$5,871,320	$14,391,995,485	$1,370,666,629	$186,901,967	$60,847,301	$247,749,268
2022	$5,081,439	$15,122,522,824	$366,719,933	$192,495,323	$34,620,868	$227,116,191
2023	$5,695,940	$15,873,026,857	$1,951,567,977	$198,278,679	$56,004,883	$254,283,561
2024	$6,368,817	$16,600,481,579	$961,932,066	$204,135,079	$102,138,029	$306,273,109
2025	$7,105,165	$17,344,111,686	$3,927,960,879	$210,417,873	$104,648,226	$315,066,099
Total	**$124,499,107**	**$230,038,672,802**	**$17,668,122,708**	**$3,222,339,109**	**$1,313,100,489**	**$4,535,439,598**

Table 52: Strategy 06 Cycle 6 Years and 12 Years - WBC Economic Impact Performance

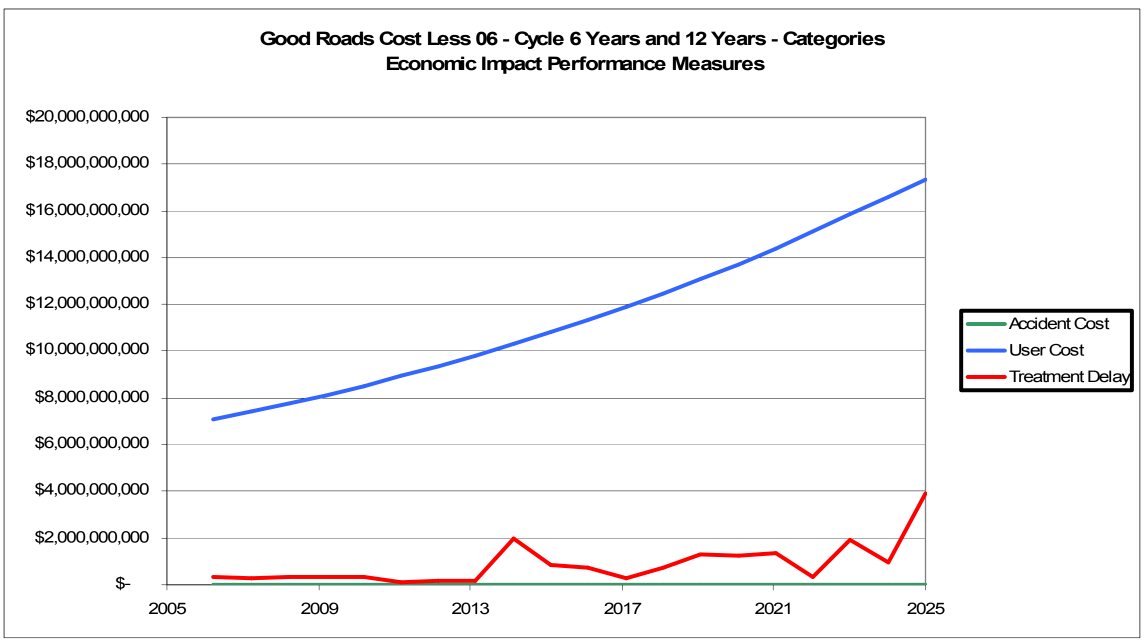


Figure 67: Strategy 06 Cycle 6 Years and 12 Years – WBC Economic Impact Performance

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	591	88	29	1	265	188	4	13	4	0	**1183**
2007	574	100	18	1	414	68	23	4	0	0	**1202**
2008	230	149	0	3	457	6	59	0	0	0	**904**
2009	139	228	2	1	417	8	23	0	0	1	**819**
2010	11	284	0	4	327	24	22	0	0	12	**684**
2011	7	219	20	7	122	48	42	0	0	26	**490**
2012	796	71	20	33	211	56	5	13	3	7	**1214**
2013	972	3	11	15	231	3	49	4	0	15	**1303**
2014	477	90	0	14	123	16	56	0	20	8	**802**
2015	283	9	0	74	73	3	65	11	29	0	**547**
2016	258	0	0	34	38	4	25	40	36	0	**435**
2017	145	1	0	6	0	0	40	61	9	29	**290**
2018	581	0	0	26	69	124	27	46	14	5	**892**
2019	760	0	0	98	73	68	37	45	8	0	**1088**
2020	688	0	0	26	321	0	27	0	11	0	**1074**
2021	436	0	0	68	334	0	61	13	0	0	**912**
2022	185	0	0	94	247	12	44	3	0	2	**587**
2023	59	0	0	124	174	6	38	52	0	0	**452**
2024	361	0	0	23	396	38	46	195	0	0	**1059**
2025	327	0	0	38	397	8	42	158	0	0	**970**
Total	**7879**	**1242**	**101**	**690**	**4690**	**679**	**731**	**657**	**134**	**103**	**16907**

Table 53: Strategy 06 Cycle 6 Years and 12 Years – WBC Treatment Distribution (miles)

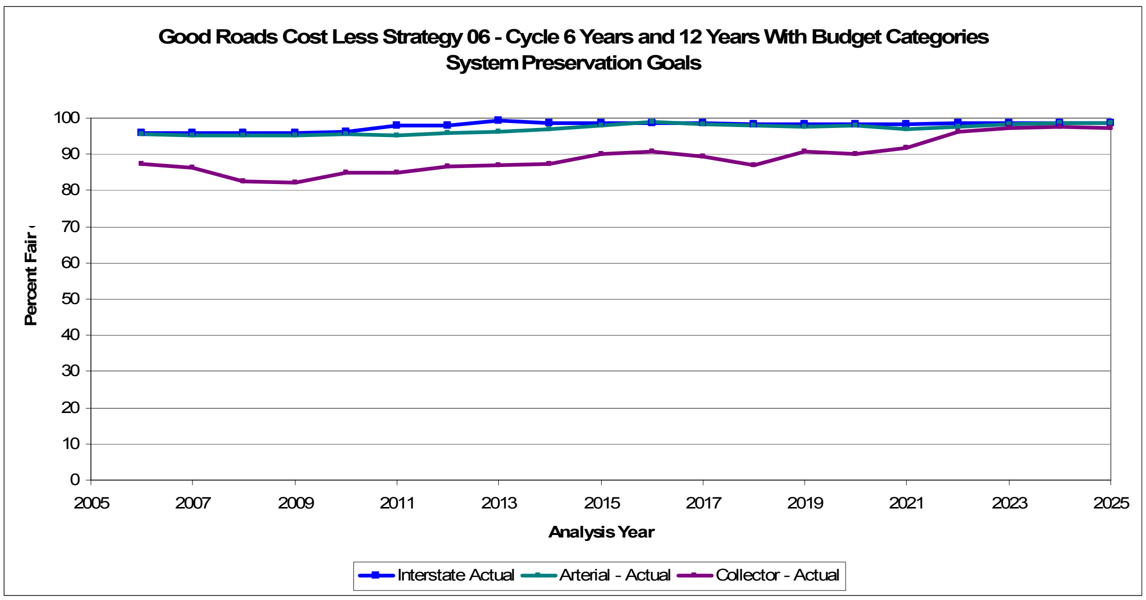


Figure 68: Strategy 06 Cycle 6 Years and 12 Years – WBC System Preservation Goals

5.3.9.2 *Discussion*

This strategy shortens the time cycle between successive minor maintenance treatments to 6 years and fixes the timing cycle for all major rehabilitation treatments to 12 years.

This strategy utilizes the Orange Book and Blue budget categories that restrict the funding within each category so the results are not quite as good as the previous strategy without budget categories, but the results are quite similar.

5.3.10 Strategy 07 – Cycle 8 Years and 10 Years-No Budget Categories

5.3.10.1 Results

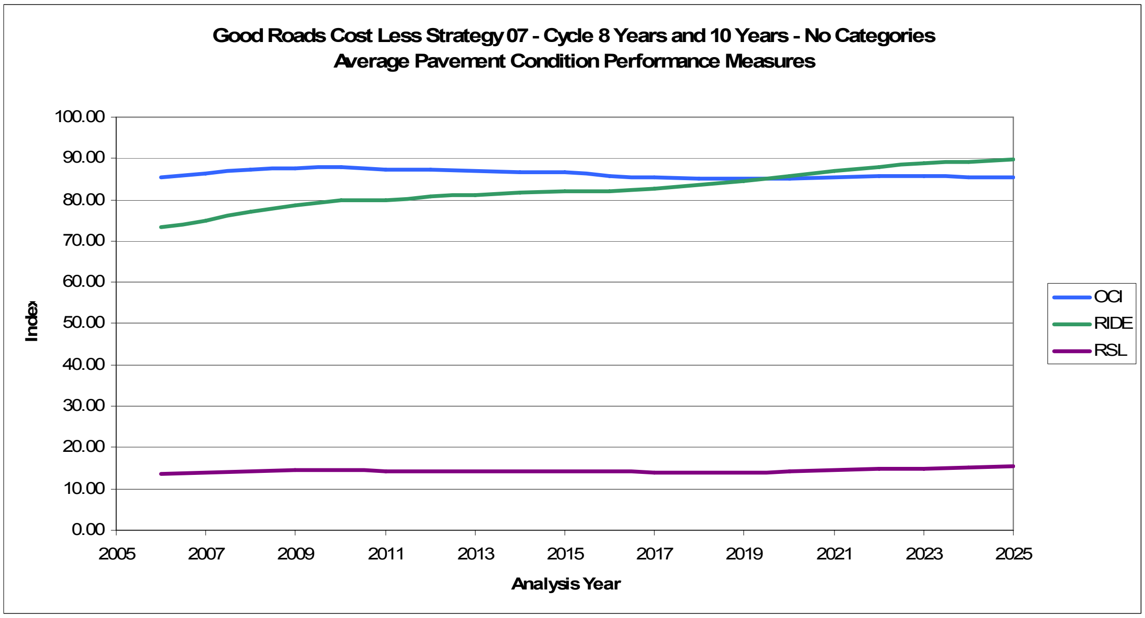


Figure 69: Strategy 07 Cycle 8 Years and 10 Years – NBC Condition Performance Measures

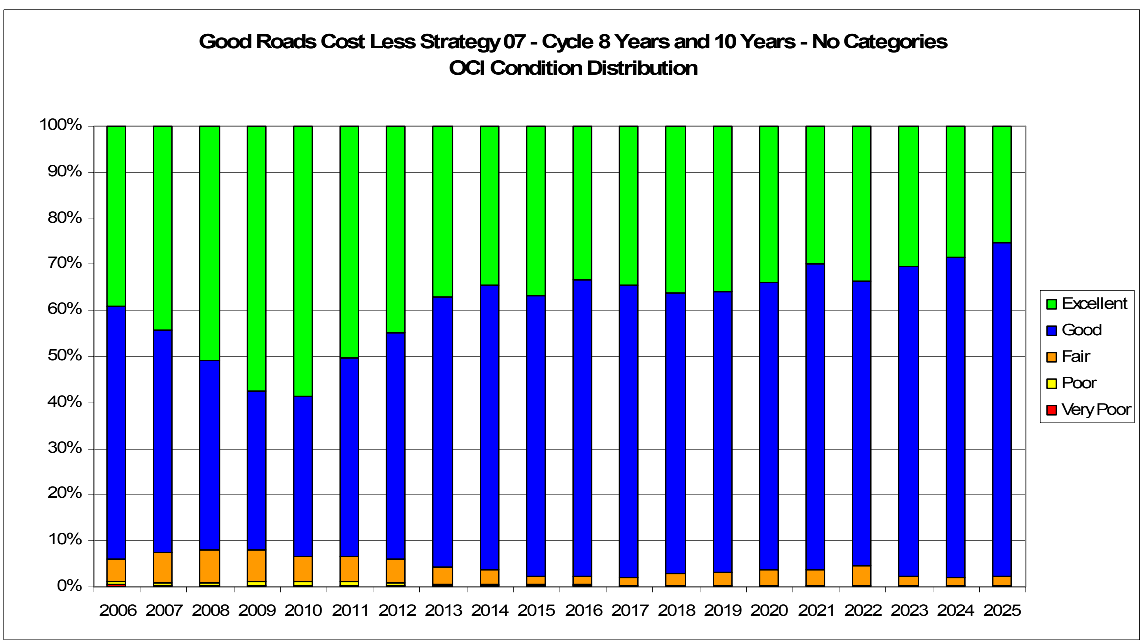


Figure 70: Strategy 07 Cycle 8 Years and 10 Years – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,797,805	$7,106,949,745	$333,055,920	$119,993,018	$59,911,100	$179,904,118
2007	$11,482,549	$7,425,941,802	$270,756,082	$123,593,137	$61,703,499	$185,296,637
2008	$9,282,555	$7,765,929,599	$330,092,674	$127,247,024	$63,614,610	$190,861,634
2009	$10,634,019	$8,127,551,296	$332,255,219	$130,902,084	$65,525,642	$196,427,727
2010	$5,059,772	$8,525,723,139	$344,200,036	$135,056,175	$67,317,303	$202,373,478
2011	$4,958,239	$8,941,620,190	$115,647,994	$139,012,682	$69,429,387	$208,442,069
2012	$3,975,630	$9,370,711,663	$153,995,451	$143,244,418	$71,583,129	$214,827,548
2013	$3,680,390	$9,823,735,481	$177,447,787	$147,464,988	$73,642,293	$221,107,282
2014	$3,589,905	$10,289,285,188	$1,954,871,085	$151,971,409	$75,638,746	$227,610,155
2015	$4,436,458	$10,797,960,627	$839,628,325	$156,352,587	$53,647,783	$210,000,370
2016	$3,743,096	$11,332,738,399	$715,628,334	$161,063,311	$36,569,530	$197,632,841
2017	$4,976,281	$11,908,202,274	$297,071,965	$166,074,922	$49,522,663	$215,597,585
2018	$5,591,048	$12,477,202,614	$711,119,935	$170,790,789	$63,924,785	$234,715,573
2019	$5,117,170	$13,084,859,543	$1,278,581,282	$176,028,511	$79,006,568	$255,035,079
2020	$5,051,510	$13,728,122,812	$1,234,923,137	$181,315,131	$63,804,143	$245,119,275
2021	$5,871,320	$14,391,995,485	$1,370,666,629	$186,901,967	$60,847,301	$247,749,268
2022	$5,081,439	$15,122,522,824	$366,719,933	$192,495,323	$34,620,868	$227,116,191
2023	$5,695,940	$15,873,026,857	$1,951,567,977	$198,278,679	$56,004,883	$254,283,561
2024	$6,368,817	$16,600,481,579	$961,932,066	$204,135,079	$102,138,029	$306,273,109
2025	$7,105,165	$17,344,111,686	$3,927,960,879	$210,417,873	$104,648,226	$315,066,099
Total	**$124,499,107**	**$230,038,672,802**	**$17,668,122,708**	**$3,222,339,109**	**$1,313,100,489**	**$4,535,439,598**

Table 54: Strategy 07 Cycle 8 Years and 10 Years – NBC Economic Impact Performance

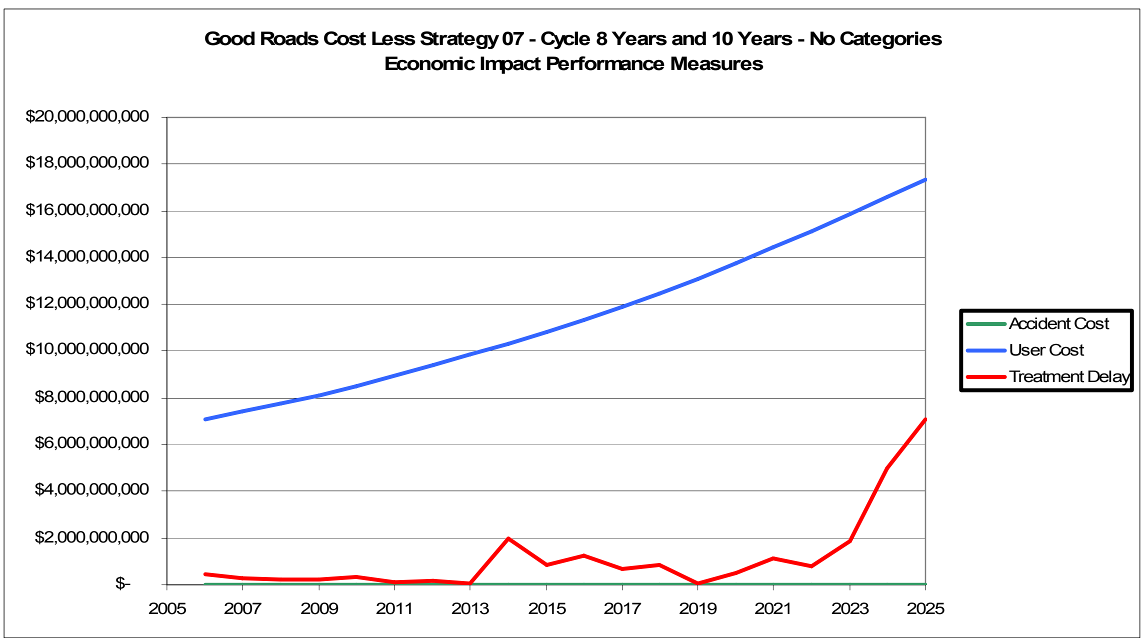


Figure 71: Strategy 07 Cycle 8 Years and 10 Years – NBC Economic Impact Performance

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	605	212	31	1	140	137	45	17	4	0	**1192**
2007	434	222	16	0	317	60	32	0	0	0	**1082**
2008	319	197	26	1	447	28	18	0	0	0	**1036**
2009	127	81	14	1	563	10	14	0	0	1	**812**
2010	61	157	20	6	444	23	44	0	0	0	**755**
2011	0	42	15	4	153	42	4	0	3	44	**307**
2012	0	103	6	22	324	52	16	0	0	13	**536**
2013	2	89	11	8	302	12	0	1	18	10	**453**
2014	738	10	0	20	156	16	63	6	31	0	**1039**
2015	520	21	0	31	74	3	51	28	26	12	**766**
2016	56	0	0	16	107	98	17	49	16	17	**376**
2017	24	0	0	27	319	54	7	21	16	5	**474**
2018	26	0	0	22	553	26	3	0	6	0	**637**
2019	33	0	0	73	471	13	7	0	7	0	**603**
2020	76	0	0	36	567	25	12	0	0	0	**715**
2021	28	0	0	31	644	35	14	0	0	0	**751**
2022	382	0	0	35	453	57	26	15	0	2	**970**
2023	137	0	0	101	418	21	26	18	0	0	**721**
2024	78	0	0	22	482	33	25	145	0	0	**785**
2025	95	0	0	8	600	35	13	75	0	0	**826**
Total	**3740**	**1132**	**138**	**467**	**7535**	**780**	**437**	**375**	**127**	**103**	**14834**

Table 55: Strategy 07 Cycle 8 Years and 10 Years – NBC Treatment Distribution (miles)

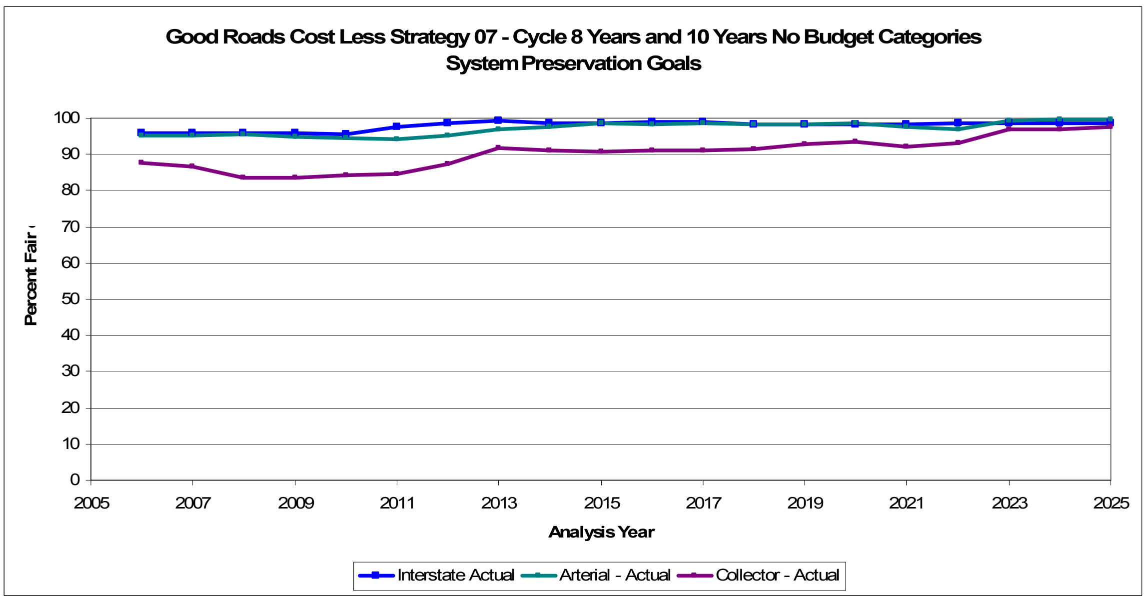


Figure 72: Strategy 07 Cycle 8 Years and 10 Years – NBC System Preservation Goals

5.3.10.2 Discussion

This strategy sets the time cycle between successive minor maintenance treatments to 8 years and fixes the timing cycle for all major rehabilitation treatments to 10 years.

Once again this strategy is quite similar to the previous strategies except in terms of the Delay costs where they have increased due to the shortened cycle of 10 years.

5.3.11 Strategy 07 – Cycle 8 Years and 10 Years-With Budget Categories

5.3.11.1 *Results*

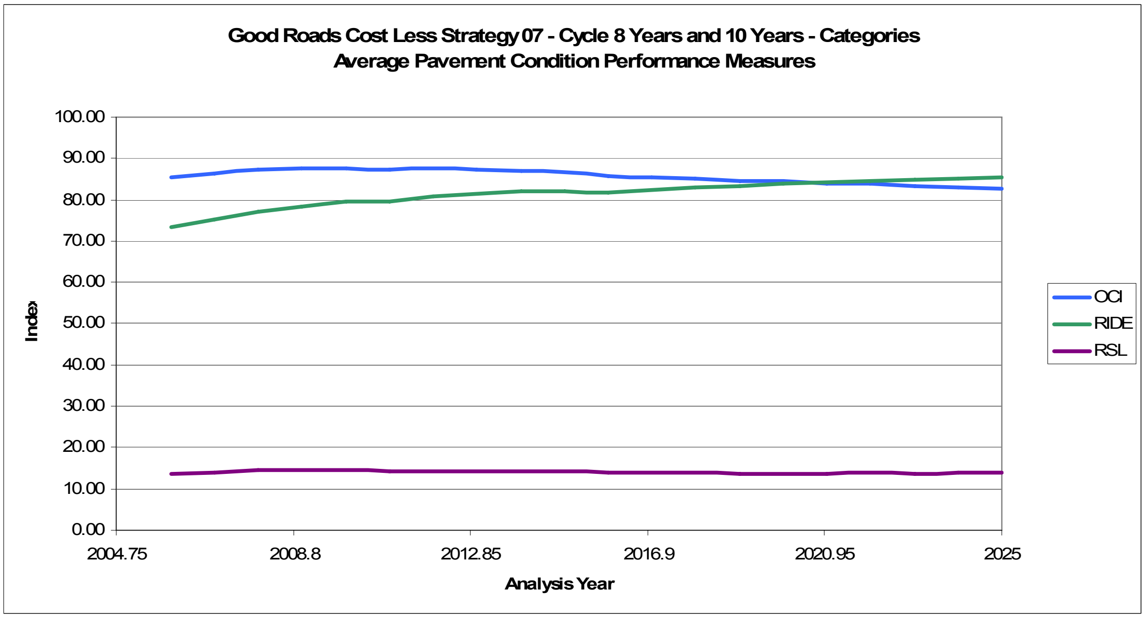


Figure 73: Strategy 07 Cycle 8 Years and 10 Years – WBC Condition Performance Measures

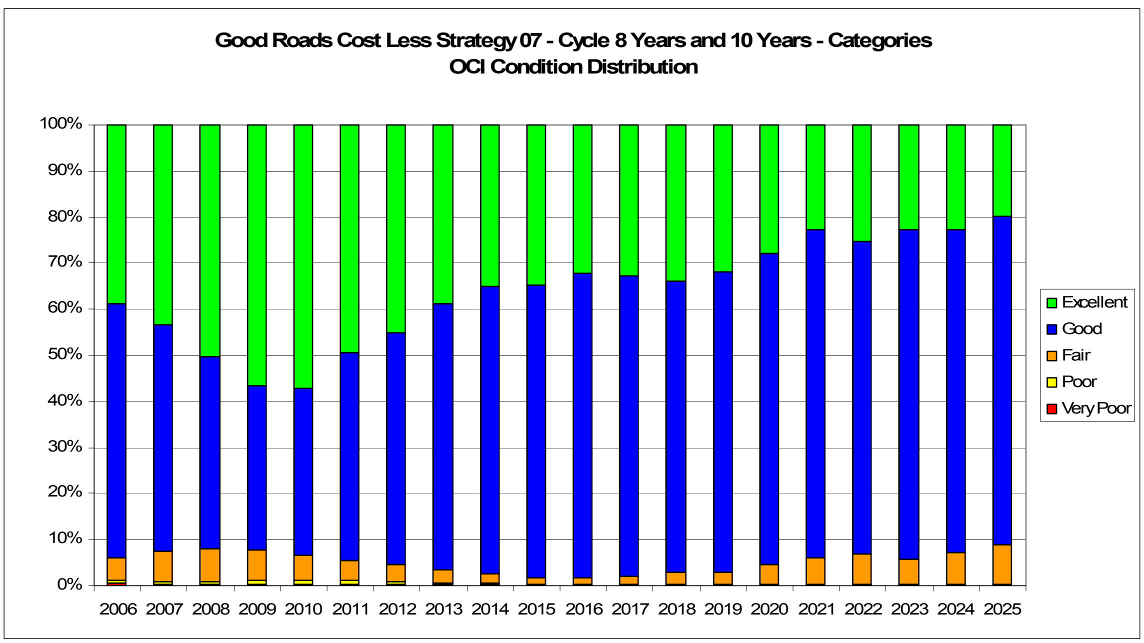


Figure 74: Strategy 07 Cycle 8 Years and 10 Years – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,165,789	$7,094,543,125	$460,015,517	$119,972,889	$59,806,583	$179,779,472
2007	$11,776,928	$7,406,500,687	$385,840,796	$123,585,955	$61,712,084	$185,298,039
2008	$10,575,856	$7,757,617,849	$237,937,606	$127,289,767	$63,563,859	$190,853,626
2009	$8,060,961	$8,131,104,782	$91,470,463	$131,030,021	$65,473,812	$196,503,833
2010	$8,370,501	$8,526,658,862	$352,234,974	$135,054,624	$67,529,296	$202,583,920
2011	$9,796,399	$8,947,722,727	$143,588,534	$138,963,296	$69,447,893	$208,411,189
2012	$7,857,624	$9,384,863,866	$166,407,345	$143,200,828	$71,630,606	$214,831,434
2013	$7,690,432	$9,862,232,336	$32,358,051	$147,384,081	$50,013,845	$197,397,926
2014	$7,299,863	$10,312,077,435	$2,237,015,825	$151,838,371	$75,835,896	$227,674,267
2015	$1,798,504	$10,804,073,571	$532,945,140	$156,527,345	$59,281,215	$215,808,560
2016	$1,145,252	$11,325,605,270	$1,051,282,418	$161,238,572	$17,388,370	$178,626,942
2017	$3,114,389	$11,889,941,738	$590,817,486	$166,026,734	$30,533,293	$196,560,027
2018	$5,244,233	$12,483,731,159	$760,746,014	$171,039,224	$11,406,607	$182,445,831
2019	$4,077,014	$13,116,065,034	$97,293,192	$176,139,167	$15,036,112	$191,175,279
2020	$4,637,901	$13,775,547,796	$515,557,843	$181,486,895	$16,196,316	$197,683,211
2021	$5,405,877	$14,465,967,470	$373,195,534	$186,953,275	$22,010,198	$208,963,473
2022	$4,714,320	$15,174,452,646	$1,933,347,550	$192,471,973	$39,943,873	$232,415,845
2023	$5,285,249	$15,932,554,763	$1,771,671,988	$198,318,717	$35,959,673	$234,278,390
2024	$5,909,754	$16,653,054,614	$4,389,475,576	$204,207,967	$56,849,387	$261,057,354
2025	$6,592,425	$17,371,378,685	$7,688,120,179	$210,405,218	$48,345,269	$258,750,486
Total	**$131,519,274**	**$230,415,694,414**	**$23,811,322,031**	**$3,223,134,918**	**$937,964,185**	**$4,161,099,103**

Table 56: Strategy 07 Cycle 8 Years and 10 Years – WBC Economic Impact Performance

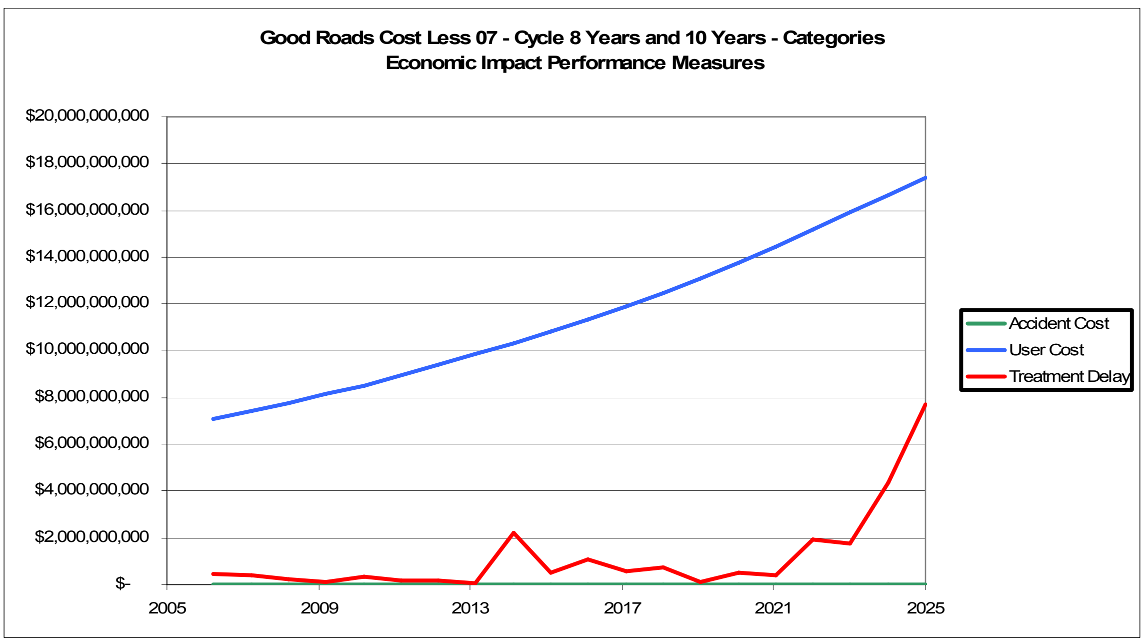


Figure 75: Strategy 07 Cycle 8 Years and 10 Years – WBC Economic Impact Performance

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	534	79	41	1	230	166	26	15	4	0	**1095**
2007	416	128	16	0	416	64	44	2	0	0	**1085**
2008	422	177	26	1	456	7	8	0	0	0	**1097**
2009	103	220	2	4	426	18	28	0	0	1	**801**
2010	11	251	15	1	292	13	31	0	3	12	**630**
2011	17	238	20	0	94	38	17	3	0	32	**459**
2012	10	256	6	26	320	59	7	0	0	0	**682**
2013	2	179	11	15	239	12	0	1	2	15	**477**
2014	715	29	0	15	109	16	46	23	24	8	**985**
2015	481	0	0	20	76	0	60	40	41	0	**718**
2016	154	0	0	19	61	104	8	21	14	12	**393**
2017	204	1	0	8	311	60	21	23	0	12	**641**
2018	105	0	0	0	512	26	8	0	0	0	**650**
2019	94	0	0	0	403	1	15	0	7	0	**519**
2020	233	0	0	5	440	35	4	0	0	0	**717**
2021	115	0	0	0	487	28	12	13	0	0	**654**
2022	464	0	0	17	312	60	14	2	0	2	**871**
2023	128	0	0	35	362	13	37	18	0	0	**593**
2024	90	0	0	4	454	45	12	130	0	0	**735**
2025	74	0	0	0	434	43	33	84	0	0	**668**
Total	**4370**	**1557**	**136**	**173**	**6432**	**808**	**429**	**375**	**96**	**93**	**14469**

Table 57: Strategy 07 Cycle 8 Years and 10 Years – WBC Treatment Distribution (miles)

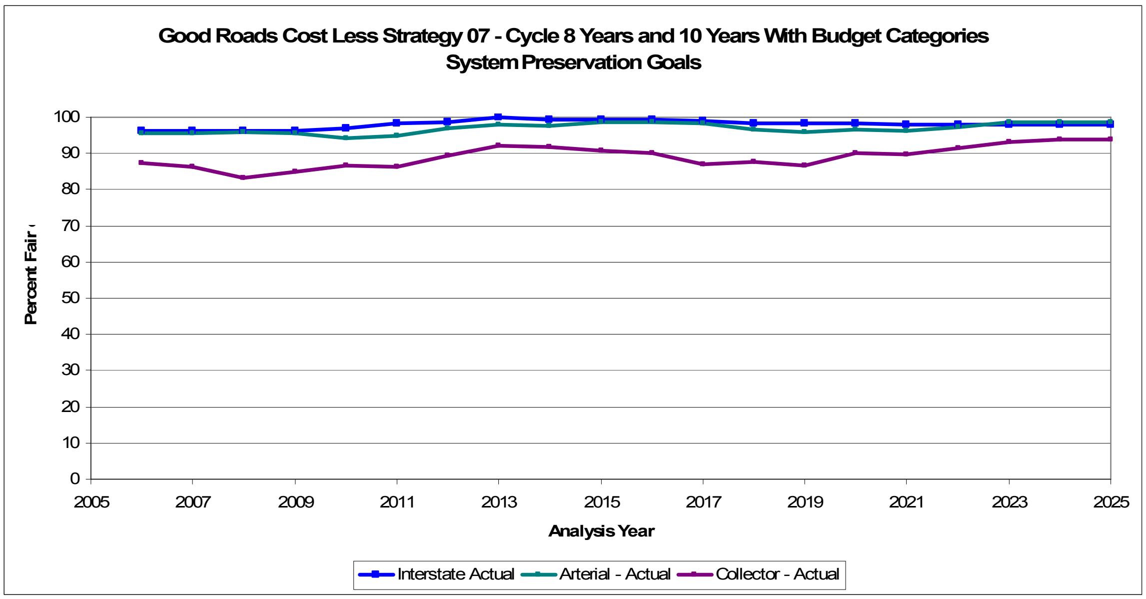


Figure 76: Strategy 07 Cycle 8 Years and 10 Years – WBC System Preservation Goals

5.3.11.2 Discussion

This strategy sets the time cycle between successive minor maintenance treatments to 8 years and fixes the timing cycle for all major rehabilitation treatments to 10 years.

Once again this strategy is quite similar to the previous strategies except in terms of the Delay costs where they have increased due to the shortened cycle of 10 years.

5.3.12 Strategy 08 – Cycle 8 Years and 12 Years-No Budget Categories

5.3.12.1 Results

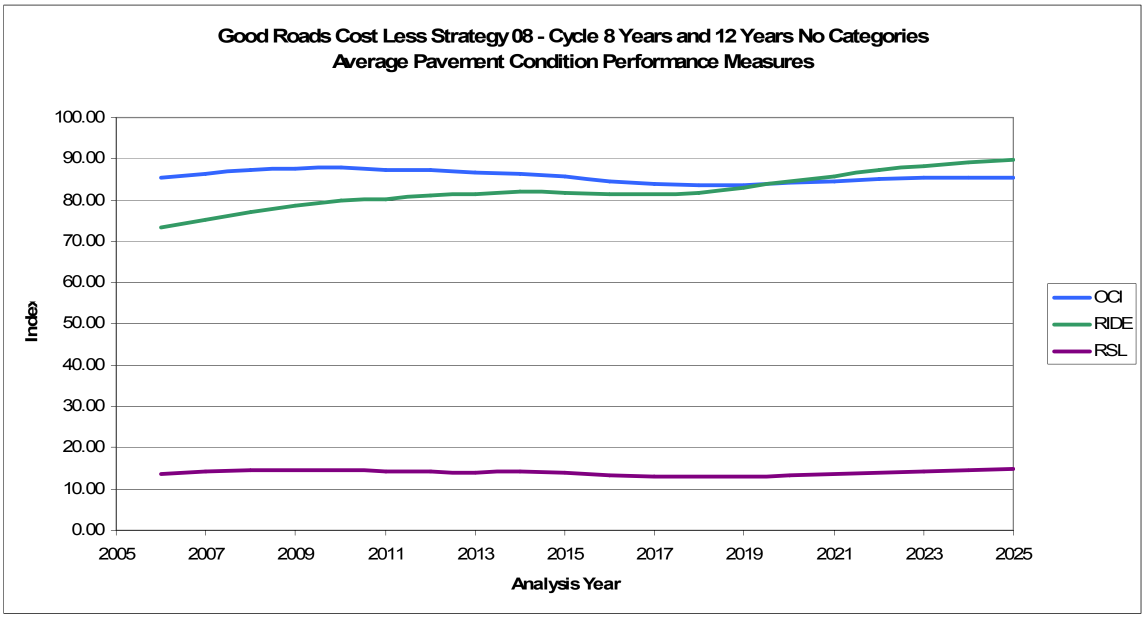


Figure 77: Strategy 08 Cycle 8 Years and 12 Years – NBC Condition Performance Measures

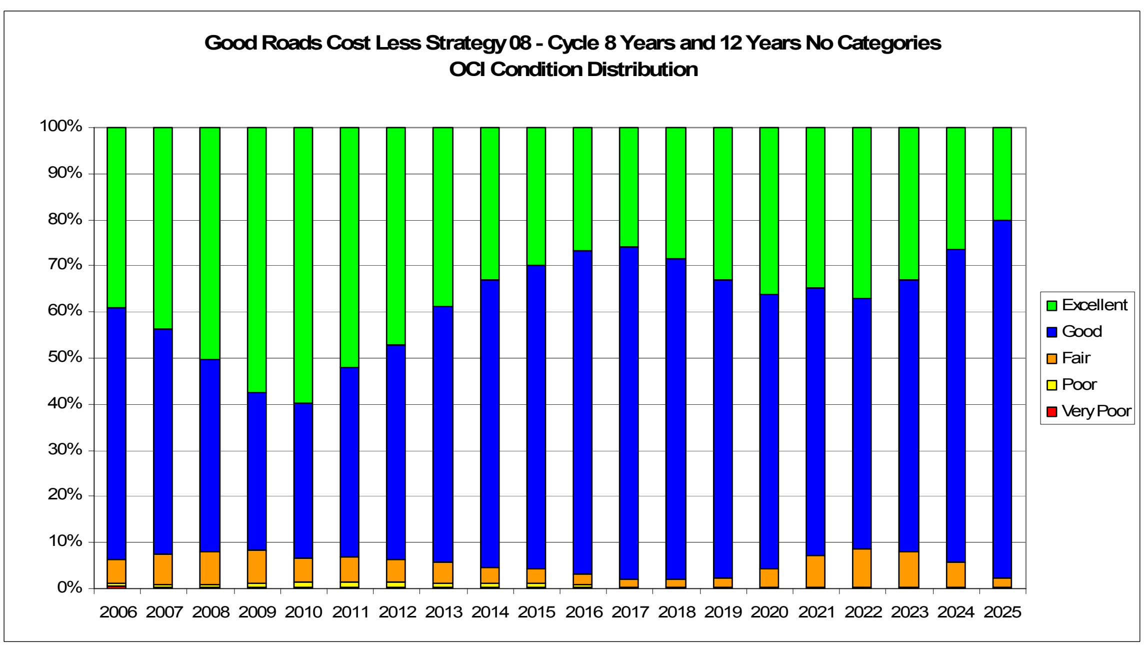


Figure 78: Strategy 08 Cycle 8 Years and 12 Years – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,385,318	$7,098,713,575	$393,535,179	$96,067,771	$83,922,208	$179,989,979
2007	$12,444,484	$7,427,150,042	$121,906,894	$130,818,206	$54,581,240	$185,399,447
2008	$10,997,394	$7,766,312,977	$353,777,665	$124,558,976	$66,371,492	$190,930,468
2009	$10,509,532	$8,127,851,266	$348,232,781	$162,191,476	$34,485,307	$196,676,784
2010	$6,356,930	$8,523,916,161	$365,869,527	$154,238,282	$48,292,485	$202,530,767
2011	$7,985,155	$8,945,385,708	$105,246,939	$195,954,489	$12,575,942	$208,530,431
2012	$6,844,790	$9,381,937,591	$336,216,359	$180,170,689	$34,608,898	$214,779,587
2013	$3,063,025	$9,851,515,938	$250,603,265	$188,737,561	$32,617,917	$221,355,478
2014	$3,314,112	$10,327,272,257	$2,061,363,744	$178,924,914	$48,782,574	$227,707,488
2015	$4,423,910	$10,853,895,590	$180,277,173	$211,961,980	$22,868,210	$234,830,190
2016	$3,315,378	$11,381,202,225	$959,132,743	$225,222,855	$16,397,339	$241,620,194
2017	$3,247,933	$11,971,928,175	$59,157,932	$233,343,724	$15,427,485	$248,771,209
2018	$3,719,290	$12,551,403,346	$533,792,416	$247,968,740	$8,384,290	$256,353,031
2019	$4,239,897	$13,145,001,177	$511,329,593	$254,128,606	$10,088,382	$264,216,988
2020	$4,817,399	$13,756,841,248	$2,450,267,867	$264,625,259	$7,541,956	$272,167,215
2021	$5,603,424	$14,398,710,607	$2,107,521,865	$270,856,875	$9,470,382	$280,327,257
2022	$4,931,467	$15,097,407,592	$1,002,660,965	$227,820,460	$60,952,293	$288,772,752
2023	$5,523,671	$15,823,353,471	$2,300,744,184	$252,595,042	$44,822,843	$297,417,885
2024	$6,171,257	$16,581,097,597	$2,863,598,535	$275,841,535	$30,449,729	$306,291,264
2025	$6,878,963	$17,389,980,990	$2,746,115,076	$279,963,381	$35,619,781	$315,583,162
Total	**$126,773,328**	**$230,400,877,532**	**$20,051,350,702**	**$4,155,990,823**	**$678,260,753**	**$4,834,251,576**

Table 58: Strategy 08 Cycle 8 Years and 12 Years – NBC Economic Impact Performance

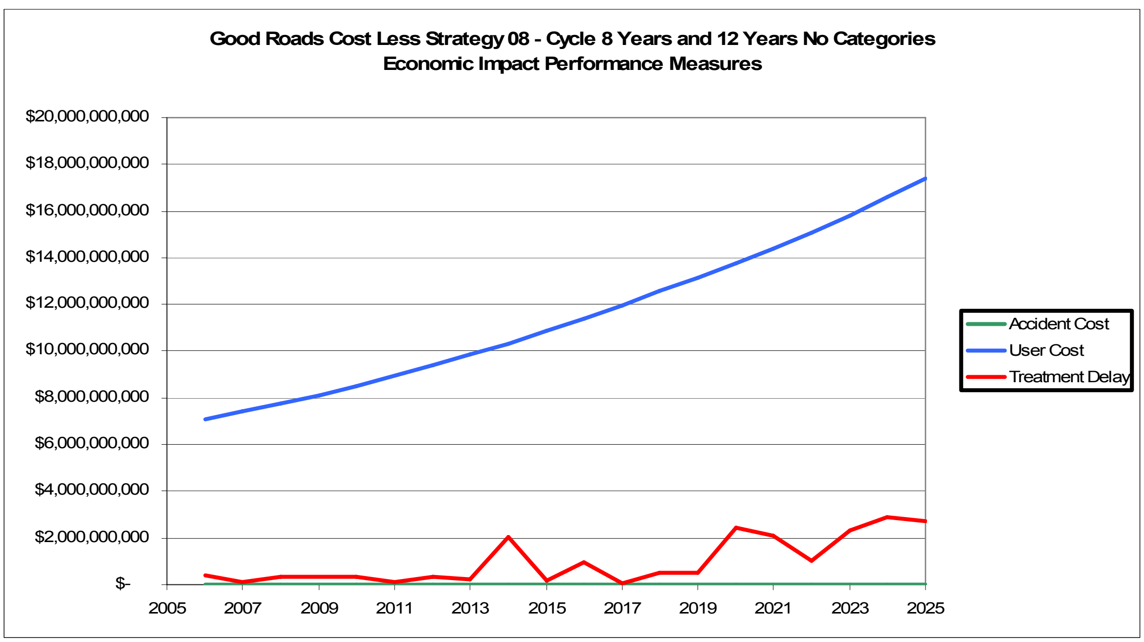


Figure 79: Strategy 08 Cycle 8 Years and 12 Years – NBC Economic Impact Performance

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	560	168	19	1	172	185	36	17	4	0	**1162**
2007	402	119	16	1	442	45	19	0	0	0	**1044**
2008	302	177	0	1	466	35	34	0	0	0	**1015**
2009	89	67	2	1	562	8	27	0	0	1	**757**
2010	37	129	6	10	464	30	46	0	3	0	**724**
2011	10	23	29	4	179	45	8	0	0	41	**338**
2012	0	100	17	28	384	55	10	0	0	5	**599**
2013	2	113	0	16	206	1	0	1	7	20	**368**
2014	459	13	0	47	152	17	36	4	34	0	**761**
2015	101	0	0	31	97	0	32	9	29	24	**324**
2016	40	0	0	34	0	4	10	52	30	10	**180**
2017	48	0	0	96	15	0	21	19	39	0	**238**
2018	35	0	0	40	241	130	10	0	10	11	**477**
2019	22	0	0	12	653	26	14	0	0	0	**727**
2020	72	0	0	0	702	44	6	0	0	0	**825**
2021	64	0	0	0	732	11	7	0	0	0	**814**
2022	571	0	0	27	525	25	28	16	0	2	**1193**
2023	163	0	0	31	504	67	39	20	0	0	**825**
2024	66	0	0	86	429	53	16	65	0	0	**715**
2025	230	0	0	133	321	8	28	20	0	0	**739**
Total	**3272**	**910**	**89**	**600**	**7248**	**790**	**426**	**223**	**156**	**115**	**13829**

Table 59: Strategy 08 Cycle 8 Years and 12 Years – NBC Treatment Distribution (miles)

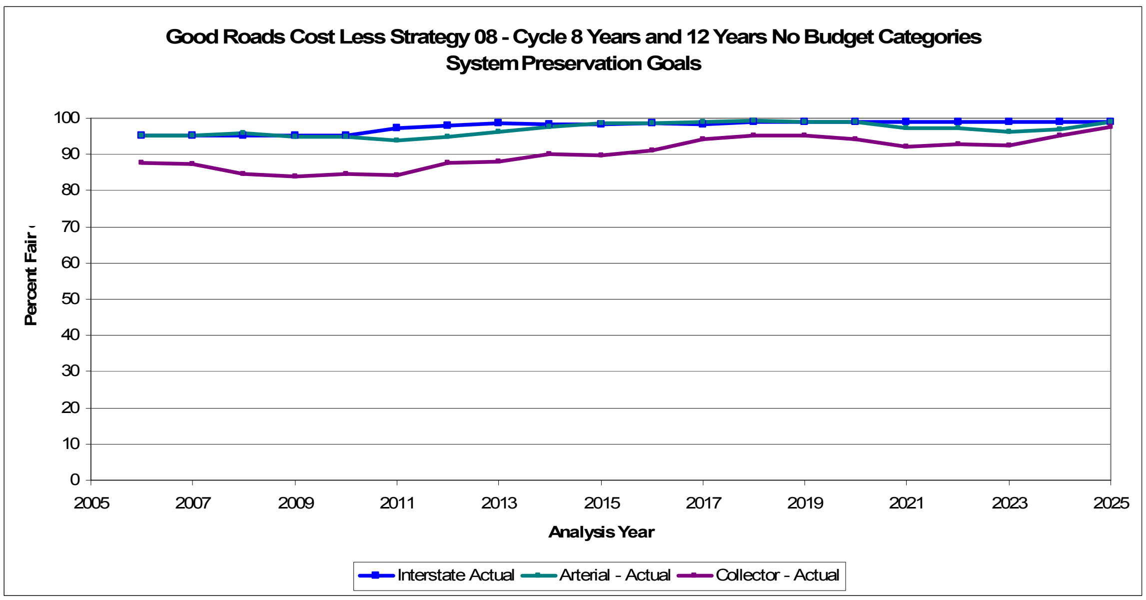


Figure 80: Strategy 08 Cycle 8 Years and 12 Years – NBC System Preservation Goals

5.3.12.2 Discussion

This strategy sets the time cycle between successive minor maintenance treatments to 8 years and fixes the timing cycle for all major rehabilitation treatments to 12 years.

Once again this strategy is quite similar to results obtained within the previous strategies where the timing cycles were modified.

5.3.13 Strategy 08 – Cycle 8 Years and 12 Years-With Budget Categories

5.3.13.1 Results

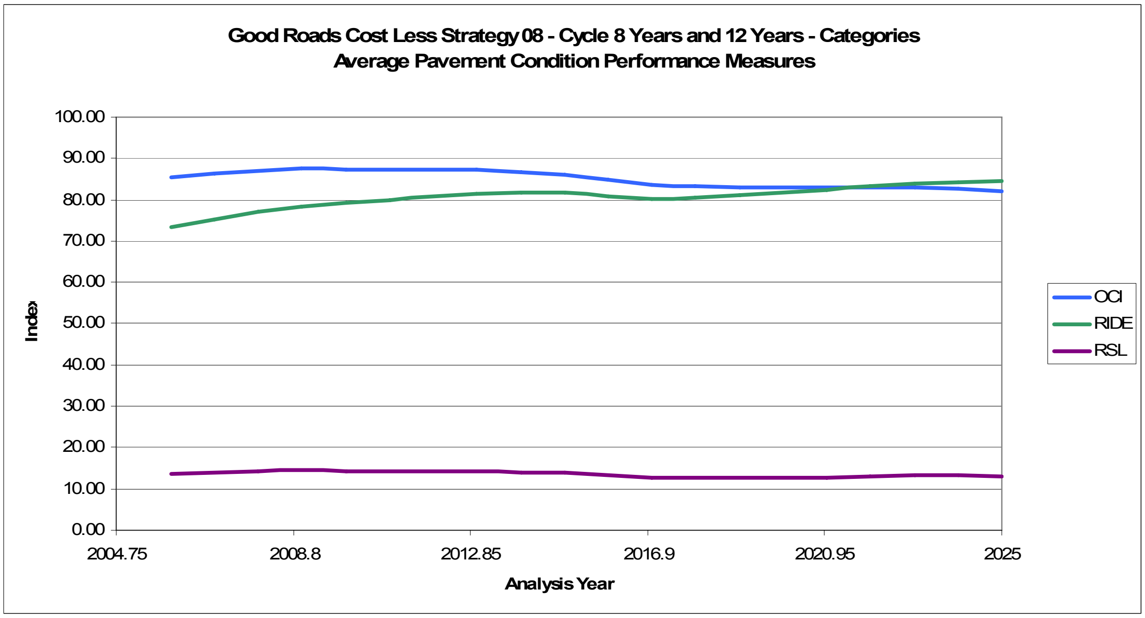


Figure 81: Strategy 08 Cycle 8 Years and 12 Years – WBC Condition Performance Measures

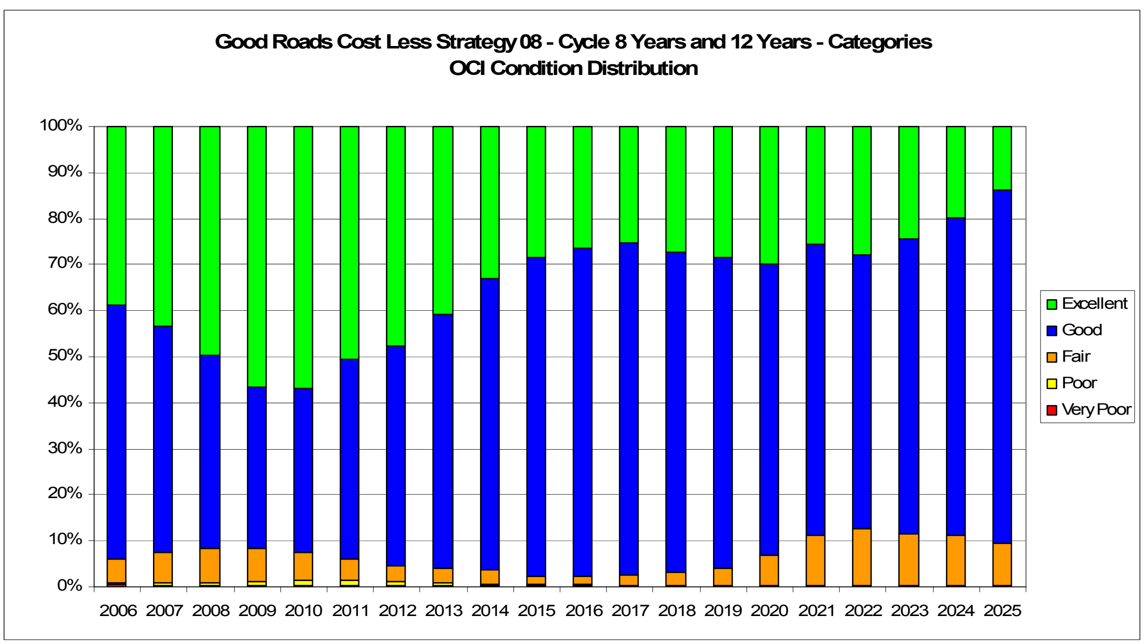


Figure 82: Strategy 08 Cycle 8 Years and 12 Years – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,262,907	$7,101,635,677	$372,229,122	$119,981,282	$59,948,340	$179,929,623
2007	$12,008,833	$7,428,559,941	$139,645,789	$123,553,491	$61,790,888	$185,344,379
2008	$10,655,754	$7,769,017,929	$336,271,063	$127,295,364	$63,564,497	$190,859,862
2009	$10,622,434	$8,126,946,500	$375,104,264	$131,124,623	$65,523,910	$196,648,532
2010	$7,116,421	$8,519,533,868	$350,613,568	$134,989,013	$67,448,844	$202,437,856
2011	$7,854,311	$8,943,790,150	$112,554,036	$139,014,988	$69,349,758	$208,364,747
2012	$6,453,975	$9,379,858,745	$364,562,075	$143,214,012	$71,539,318	$214,753,330
2013	$3,310,106	$9,854,016,647	$51,690,587	$147,561,892	$59,530,340	$207,092,232
2014	$3,123,111	$10,332,098,373	$1,876,742,218	$151,964,503	$47,160,606	$199,125,110
2015	$4,112,830	$10,853,921,451	$588,160,432	$156,311,747	$35,884,433	$192,196,179
2016	$3,388,422	$11,395,525,795	$731,701,766	$161,187,493	$30,261,187	$191,448,679
2017	$4,578,485	$11,973,293,301	$352,380,735	$165,664,476	$31,072,137	$196,736,613
2018	$3,571,692	$12,556,729,416	$534,367,192	$170,771,617	$21,452,589	$192,224,206
2019	$4,077,014	$13,153,190,044	$529,436,976	$176,199,328	$17,149,985	$193,349,313
2020	$4,637,901	$13,786,366,589	$1,987,368,940	$181,437,565	$18,576,428	$200,013,994
2021	$5,405,877	$14,426,408,756	$2,571,997,223	$186,858,054	$24,880,153	$211,738,206
2022	$4,714,320	$15,126,410,052	$735,617,620	$192,470,217	$51,721,695	$244,191,912
2023	$5,285,249	$15,861,518,994	$2,267,146,173	$198,229,162	$55,445,412	$253,674,574
2024	$5,909,754	$16,614,952,935	$3,110,707,746	$204,059,890	$30,265,571	$234,325,461
2025	$6,592,425	$17,422,471,944	$2,643,853,282	$210,236,806	$28,848,662	$239,085,468
Total	**$125,681,820**	**$230,626,247,107**	**$20,032,150,804**	**$3,222,125,522**	**$911,414,753**	**$4,133,540,275**

Table 60: Strategy 08 Cycle 8 Years and 12 Years – WBC Economic Impact Performance

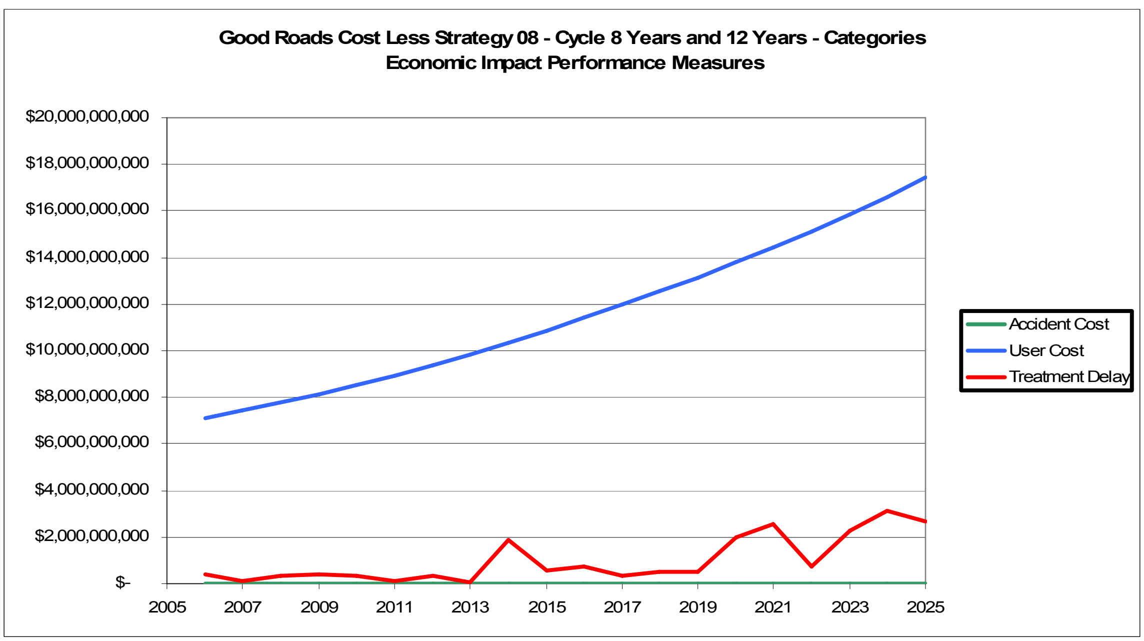


Figure 83: Strategy 08 Cycle 8 Years and 12 Years – WBC Economic Impact Performance

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	491	90	31	1	227	199	27	13	4	0	**1083**
2007	411	148	16	0	436	31	26	4	0	0	**1072**
2008	332	168	0	1	458	34	31	0	0	0	**1024**
2009	123	217	2	4	409	20	31	0	0	0	**806**
2010	21	204	6	3	253	12	48	0	0	19	**566**
2011	7	301	29	1	142	48	19	0	3	23	**572**
2012	0	237	6	16	312	59	11	0	0	3	**644**
2013	2	221	11	26	214	0	0	0	0	15	**490**
2014	471	0	0	9	136	16	30	15	26	7	**711**
2015	196	0	0	41	71	3	28	42	39	0	**420**
2016	217	0	0	2	0	4	15	52	19	24	**334**
2017	196	1	0	16	8	0	26	25	20	10	**301**
2018	141	0	0	13	216	121	22	0	8	0	**522**
2019	154	0	0	0	470	24	13	0	0	0	**660**
2020	226	0	0	7	493	16	7	0	0	0	**750**
2021	156	0	0	0	491	18	13	13	0	0	**691**
2022	508	0	0	3	463	7	22	15	0	2	**1021**
2023	140	0	0	9	476	62	38	56	0	0	**781**
2024	66	0	0	10	386	57	13	63	0	0	**595**
2025	127	0	0	58	309	7	30	25	0	0	**556**
Total	**3987**	**1588**	**101**	**220**	**5969**	**738**	**448**	**324**	**121**	**103**	**13599**

Table 61: Strategy 08 Cycle 8 Years and 12 Years – WBC Treatment Distribution (miles)

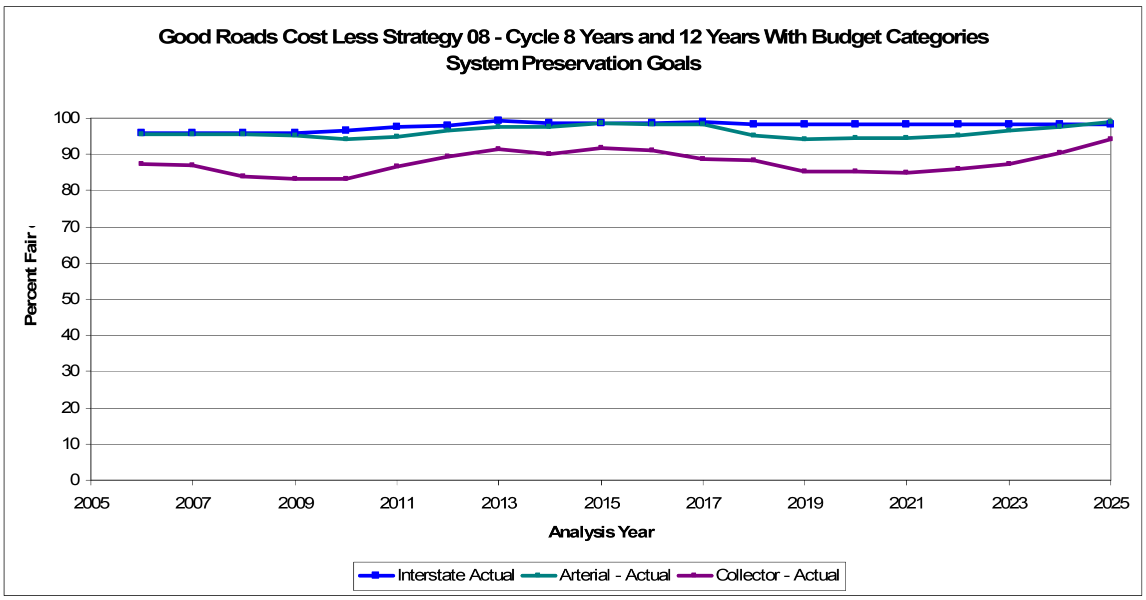


Figure 84: Strategy 08 Cycle 8 Years and 12 Years – WBC System Preservation Goals

5.3.13.2 Discussion

This strategy sets the time cycle between successive minor maintenance treatments to 8 years and fixes the timing cycle for all major rehabilitation treatments to 12 years.

Once again this strategy is quite similar to results obtained within the previous strategies where the timing cycles were modified.

5.3.14 Strategy 09 – Cycle 10 Years and 10 Years-No Budget Categories

5.3.14.1 *Results*

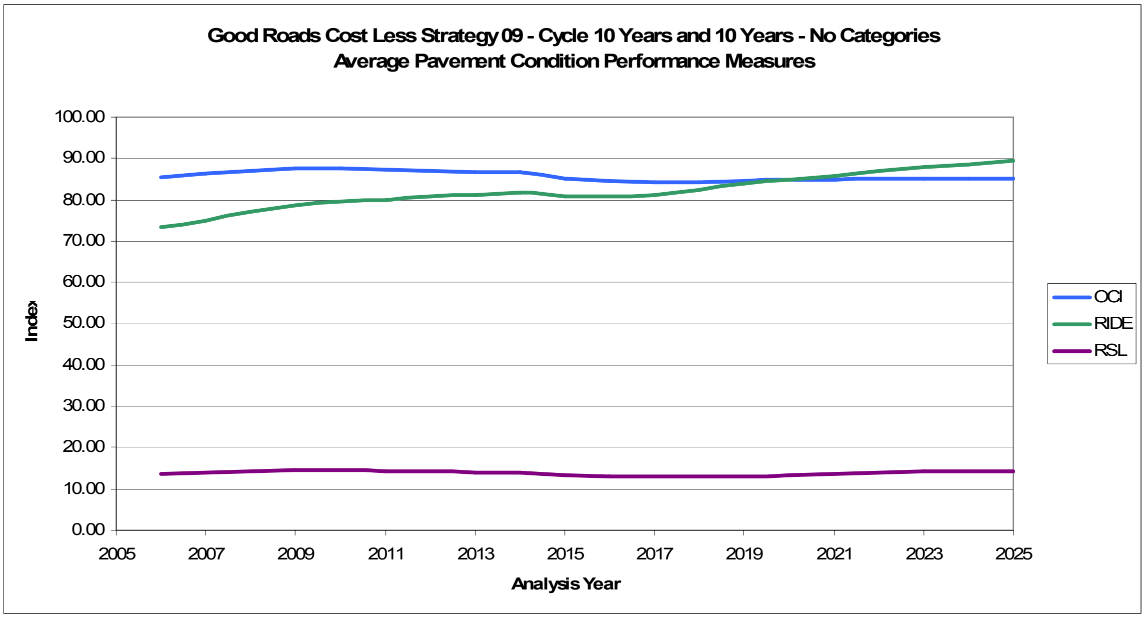


Figure 85: Strategy 09 Cycle 10 Years and 10 Years – NBC Condition Performance Measures

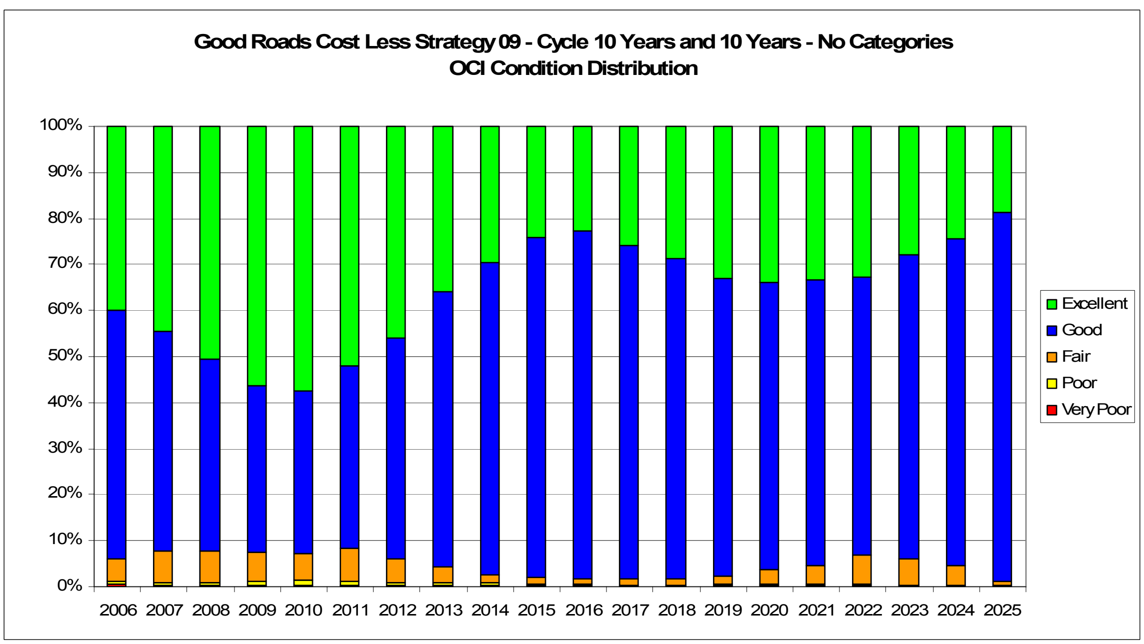


Figure 86: Strategy 09 Cycle 10 Years and 10 Years – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,302,633	$7,104,112,437	$429,780,823	$112,872,995	$67,094,117	$179,967,113
2007	$11,405,074	$7,431,690,329	$90,645,117	$127,479,318	$57,887,219	$185,366,536
2008	$9,403,376	$7,779,590,253	$177,769,259	$129,028,215	$61,931,220	$190,959,435
2009	$9,871,533	$8,130,474,889	$562,677,513	$149,127,576	$47,555,382	$196,682,958
2010	$10,175,996	$8,526,732,520	$366,314,280	$160,912,115	$41,644,913	$202,557,028
2011	$8,257,124	$8,947,178,781	$104,609,869	$163,987,094	$44,636,948	$208,624,043
2012	$7,480,147	$9,383,248,645	$350,784,566	$189,348,932	$25,443,079	$214,792,011
2013	$7,421,083	$9,858,563,904	$409,015,891	$194,037,987	$27,274,604	$221,312,591
2014	$3,177,295	$10,328,784,240	$1,825,036,694	$208,333,039	$19,525,849	$227,858,887
2015	$3,613,347	$10,851,637,331	$281,363,522	$224,636,970	$10,041,589	$234,678,560
2016	$1,818,641	$11,386,119,354	$717,108,684	$228,592,549	$13,267,850	$241,860,399
2017	$4,104,744	$11,949,971,978	$458,421,208	$240,939,644	$7,907,963	$248,847,607
2018	$3,763,176	$12,526,321,527	$695,442,072	$252,482,424	$3,449,434	$255,931,858
2019	$4,289,598	$13,137,545,000	$1,473,970,704	$254,680,102	$9,383,543	$264,063,645
2020	$4,873,464	$13,770,723,155	$1,086,438,637	$261,709,894	$10,532,515	$272,242,409
2021	$5,666,449	$14,387,138,842	$4,110,731,016	$266,664,571	$13,665,590	$280,330,161
2022	$5,002,096	$15,091,467,314	$1,608,284,817	$279,298,157	$9,354,420	$288,652,577
2023	$5,527,777	$15,847,702,497	$608,077,458	$284,149,068	$13,307,829	$297,456,897
2024	$6,175,766	$16,608,666,916	$2,821,359,187	$280,929,115	$25,490,353	$306,419,468
2025	$6,883,907	$17,420,530,650	$2,349,542,550	$311,551,524	$4,029,322	$315,580,846
Total	**$131,213,224**	**$230,468,200,562**	**$20,527,373,867**	**$4,320,761,288**	**$513,423,742**	**$4,834,185,030**

Table 62: Strategy 09 Cycle 10 Years and 10 Years – NBC Economic Impact Performance

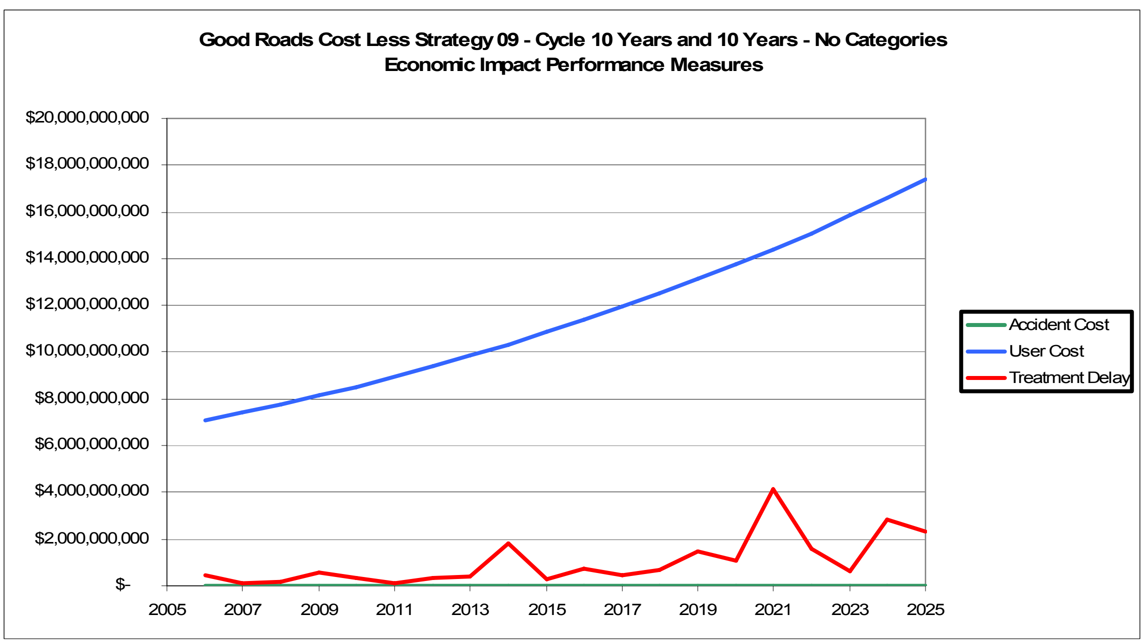


Figure 87: Strategy 09 Cycle 10 Years and 10 Years – NBC Economic Impact Performance

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	441	119	31	1	242	146	36	17	4	0	**1035**
2007	352	139	20	1	410	46	15	0	0	1	**983**
2008	407	157	26	1	467	31	20	0	0	0	**1110**
2009	248	103	8	6	499	10	26	0	0	0	**901**
2010	46	105	35	2	390	31	32	4	3	6	**654**
2011	19	156	0	4	123	53	22	0	0	38	**415**
2012	12	88	17	25	329	39	3	1	0	15	**528**
2013	3	105	0	27	226	15	5	1	26	8	**416**
2014	0	57	0	26	340	16	4	0	25	0	**468**
2015	0	14	0	3	19	0	0	0	24	34	**94**
2016	160	0	0	22	123	42	13	0	39	0	**399**
2017	52	0	0	30	396	43	10	0	15	0	**546**
2018	20	0	0	31	551	62	5	0	3	0	**673**
2019	37	0	0	24	648	26	13	0	1	0	**749**
2020	12	0	0	1	626	79	16	0	0	0	**733**
2021	7	0	0	0	623	85	28	3	0	0	**747**
2022	35	0	0	11	656	46	5	12	0	2	**766**
2023	35	0	0	52	582	45	8	3	0	0	**724**
2024	94	0	0	65	516	30	16	16	0	0	**737**
2025	46	0	0	165	285	7	0	0	0	0	**504**
Total	**2026**	**1043**	**137**	**497**	**8053**	**851**	**274**	**56**	**141**	**103**	**13181**

Table 63: Strategy 09 Cycle 10 Years and 10 Years – NBC Treatment Distribution (miles)

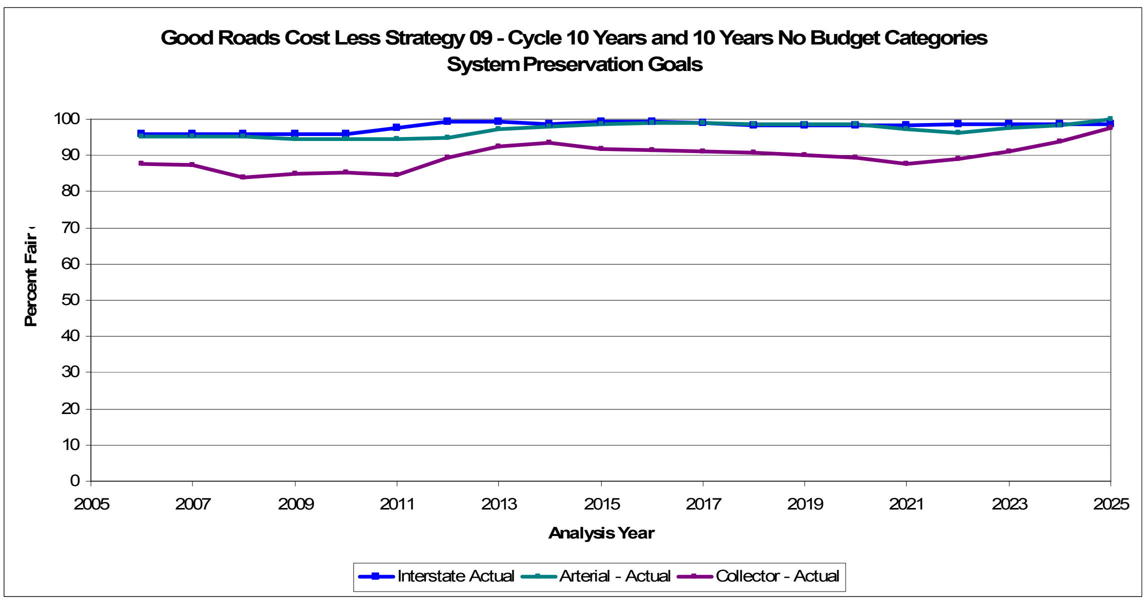


Figure 88: Strategy 09 Cycle 10 Years and 10 Years – NBC System Preservation Goals

5.3.14.2 Discussion

This strategy sets the time cycle between successive minor maintenance treatments to 10 years and fixes the timing cycle for all major rehabilitation treatments to 10 years.

Once again this strategy is quite similar to results obtained within the previous strategies where the timing cycles were modified. Based on UDOT experience though, 10 years between any treatments is too long and may not be a realistic model to implement.

5.3.15 Strategy 09 – Cycle 10 Years and 10 Years-With Budget Categories

5.3.15.1 Results

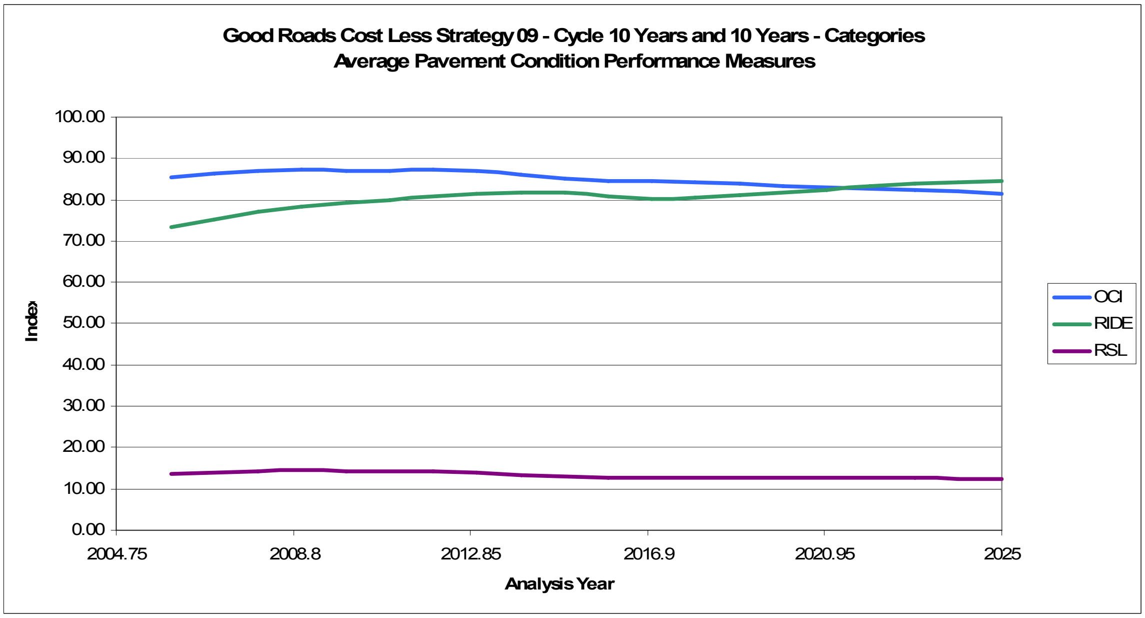


Figure 89: Strategy 09 Cycle 10 Years and 10 Years – WBC Condition Performance Measures

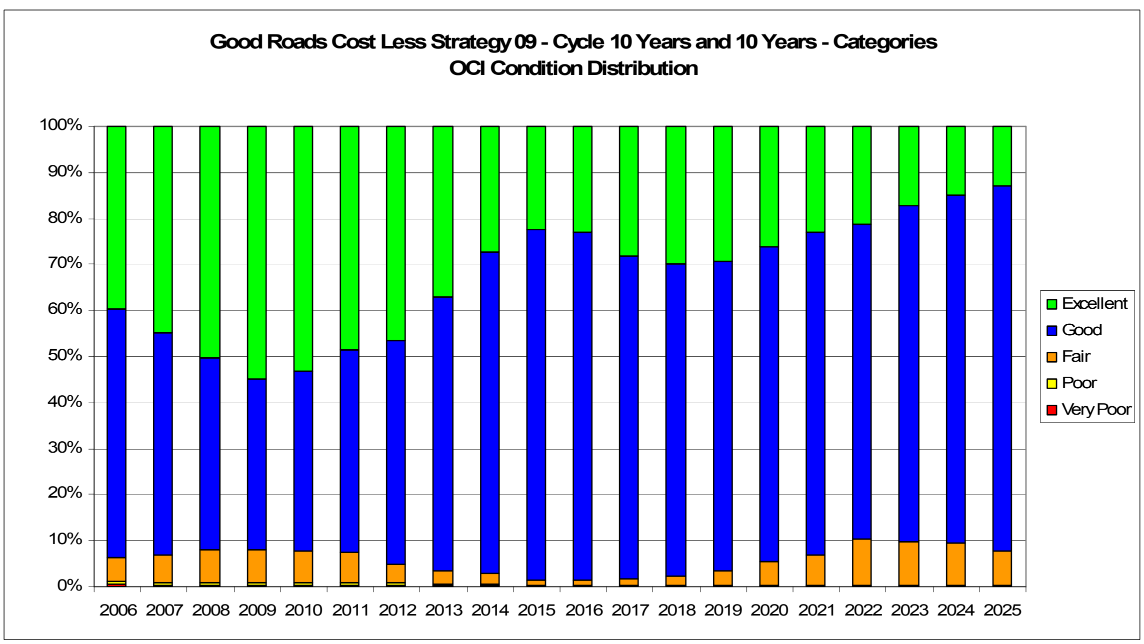


Figure 90: Strategy 09 Cycle 10 Years and 10 Years – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$12,691,357	$7,101,241,259	$388,275,431	$119,998,406	$59,879,722	$179,878,128
2007	$12,966,892	$7,436,107,976	$94,563,066	$123,597,311	$61,766,088	$185,363,399
2008	$11,061,714	$7,781,765,795	$186,205,328	$127,287,569	$63,441,115	$190,728,684
2009	$9,792,077	$8,129,586,371	$567,846,383	$131,122,672	$65,549,010	$196,671,682
2010	$8,878,736	$8,523,472,915	$347,103,411	$134,998,442	$67,362,614	$202,361,056
2011	$4,364,112	$8,943,069,144	$118,379,934	$138,948,011	$69,506,868	$208,454,879
2012	$2,683,688	$9,382,248,205	$359,601,468	$143,171,981	$71,029,703	$214,201,684
2013	$2,536,167	$9,857,384,663	$90,455,976	$147,563,752	$47,001,407	$194,565,159
2014	$1,001,471	$10,347,707,975	$1,774,501,687	$151,924,483	$3,511,612	$155,436,095
2015	$993,345	$10,871,222,295	$503,553,508	$156,567,740	$8,039,084	$164,606,824
2016	$1,145,252	$11,405,142,766	$706,897,183	$161,171,445	$33,149,028	$194,320,474
2017	$3,114,389	$11,965,575,433	$546,385,536	$166,072,714	$27,313,686	$193,386,401
2018	$3,571,692	$12,545,222,536	$707,429,171	$171,046,073	$13,377,895	$184,423,968
2019	$4,077,014	$13,151,332,395	$1,510,730,267	$176,207,357	$14,496,893	$190,704,250
2020	$4,637,901	$13,786,824,686	$1,093,505,630	$181,500,139	$17,971,610	$199,471,749
2021	$5,405,877	$14,413,989,491	$3,676,992,796	$186,901,255	$27,744,674	$214,645,929
2022	$4,714,320	$15,131,221,993	$1,521,263,369	$192,530,999	$14,728,246	$207,259,246
2023	$5,285,249	$15,900,014,830	$186,945,518	$198,194,144	$7,540,117	$205,734,261
2024	$5,909,754	$16,676,885,195	$2,669,880,388	$204,226,093	$18,838,930	$223,065,023
2025	$6,592,425	$17,487,787,525	$2,410,745,372	$210,402,694	$11,572,027	$221,974,720
Total	**$111,423,433**	**$230,837,803,448**	**$19,461,261,423**	**$3,223,433,280**	**$703,820,332**	**$3,927,253,612**

Table 64: Strategy 09 Cycle 10 Years and 10 Years – WBC Economic Impact Performance

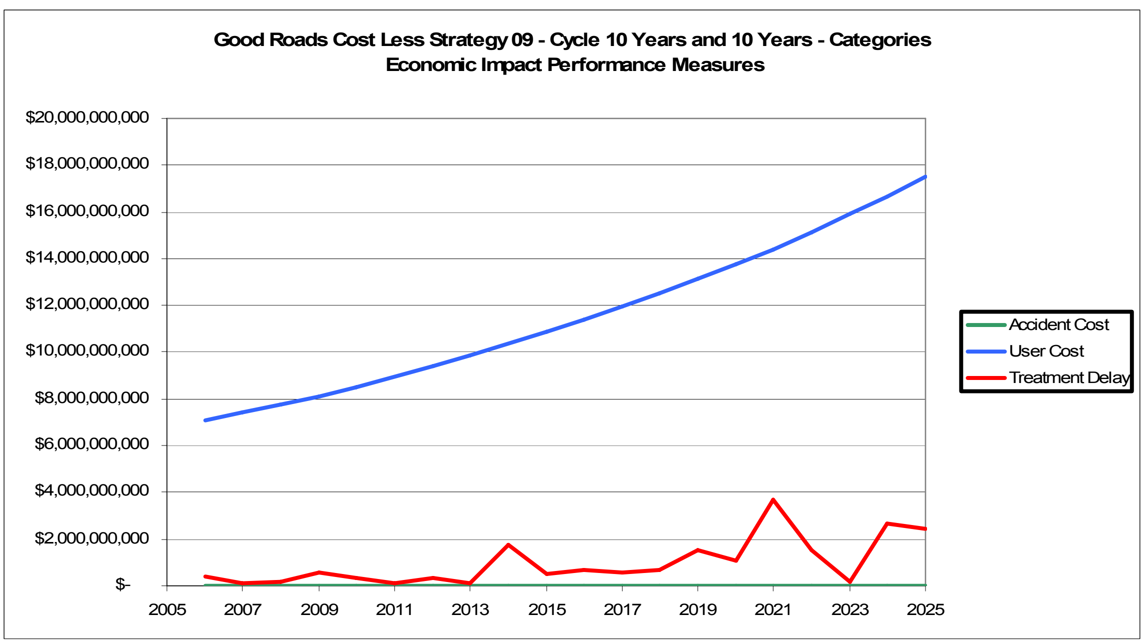


Figure 91: Strategy 09 Cycle 10 Years and 10 Years – WBC Economic Impact Performance

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	423	85	41	1	241	159	41	13	4	0	**1008**
2007	432	166	35	0	425	32	8	4	0	1	**1103**
2008	433	143	26	1	396	42	28	0	3	0	**1072**
2009	178	198	8	4	370	11	24	0	0	6	**799**
2010	15	225	20	1	122	13	28	4	0	32	**459**
2011	4	253	0	12	293	63	29	0	0	7	**659**
2012	0	268	17	17	239	33	14	1	0	13	**601**
2013	0	158	0	13	306	13	5	0	10	3	**508**
2014	0	10	0	17	95	16	0	1	26	7	**172**
2015	0	16	12	24	182	3	0	0	31	0	**268**
2016	325	38	0	0	99	42	14	0	19	12	**549**
2017	249	1	0	0	454	43	15	0	0	0	**762**
2018	138	0	0	1	424	62	9	0	0	0	**633**
2019	174	0	0	0	436	39	7	0	0	0	**656**
2020	104	0	0	0	365	92	28	0	0	0	**588**
2021	91	0	0	0	403	74	37	13	0	0	**618**
2022	95	0	0	0	468	45	14	2	0	2	**626**
2023	52	0	0	0	504	44	5	1	0	0	**606**
2024	23	0	0	13	452	29	12	16	0	0	**544**
2025	73	0	0	30	410	9	0	9	0	0	**530**
Total	**2809**	**1559**	**159**	**135**	**6682**	**865**	**317**	**62**	**94**	**81**	**12762**

Table 65: Strategy 09 Cycle 10 Years and 10 Years – WBC Treatment Distribution (miles)

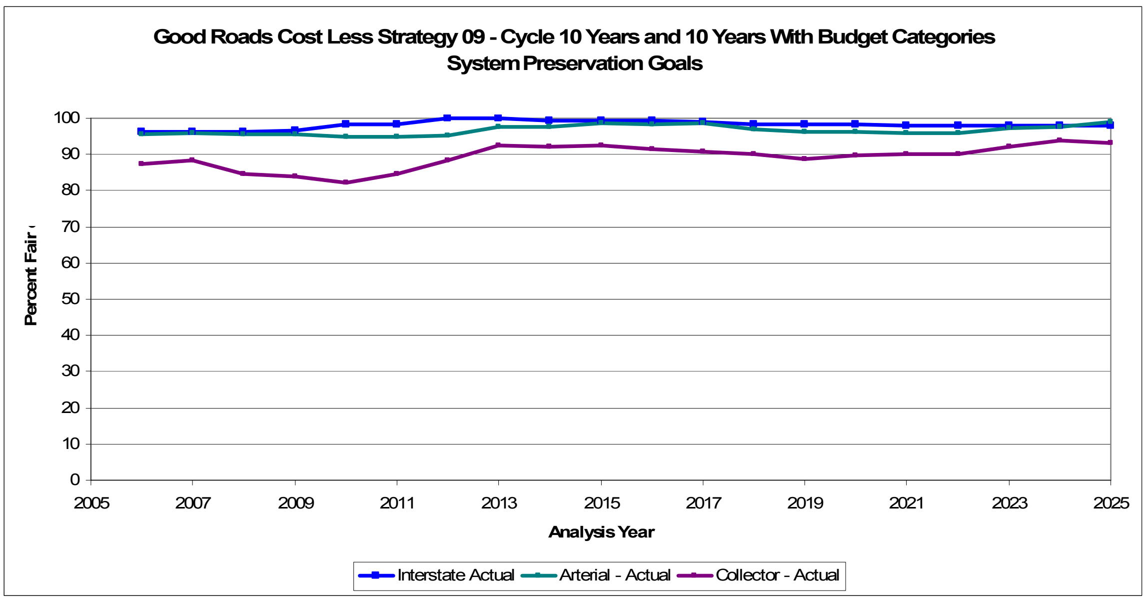


Figure 92: Strategy 09 Cycle 10 Years and 10 Years – WBC System Preservation Goals

5.3.15.2 Discussion

This strategy sets the time cycle between successive minor maintenance treatments to 10 years and fixes the timing cycle for all major rehabilitation treatments to 10 years.

Once again this strategy is quite similar to results obtained within the previous strategies where the timing cycles were modified.

5.3.16 Strategy 10 – Condition 10% less -No Budget Categories

5.3.16.1 Results

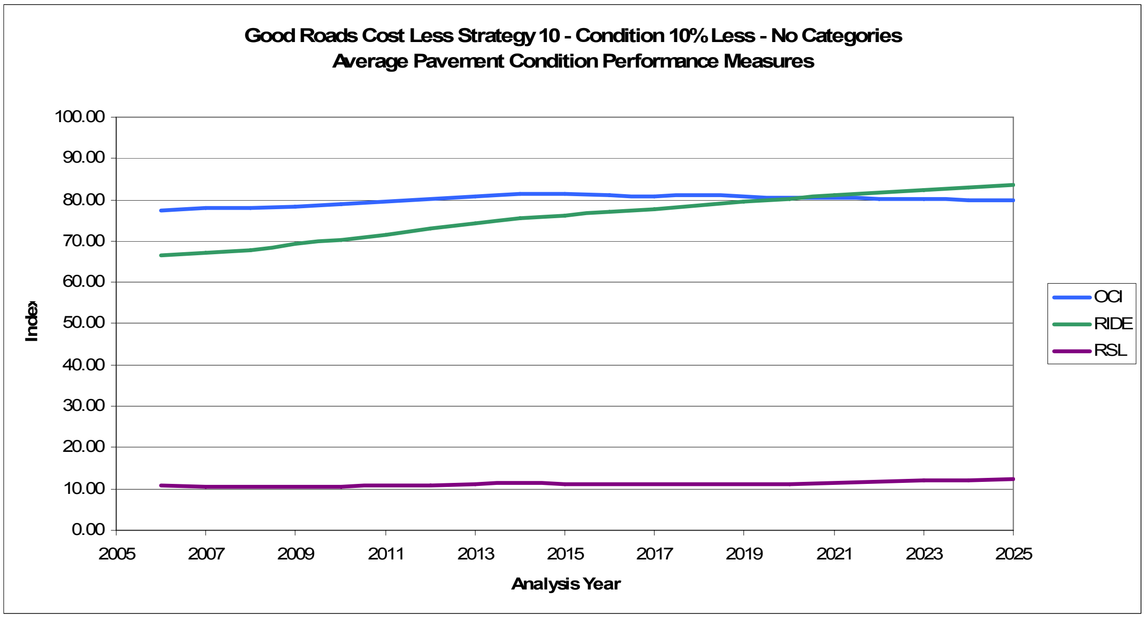


Figure 93: Strategy 10 Condition 10% less – NBC Condition Performance Measures

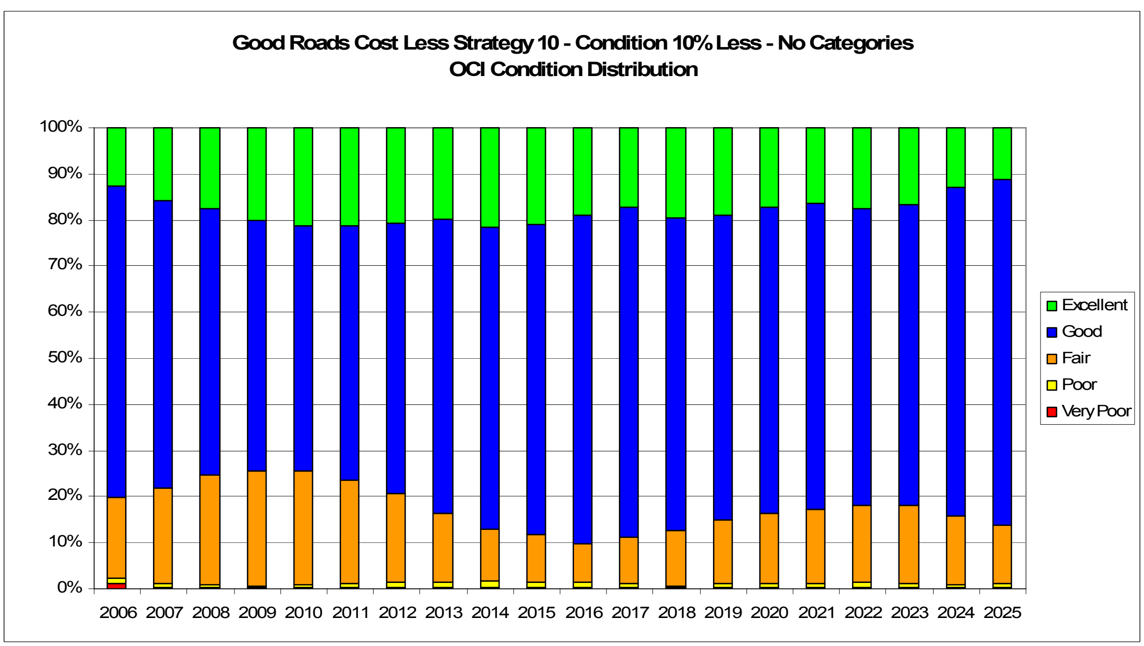


Figure 94: Strategy 10 Condition 10% less – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$29,055,647	$7,231,714,656	$119,728,437	$141,615,665	$38,378,424	$179,994,089
2007	$30,374,032	$7,580,609,812	$66,533,728	$166,199,778	$19,177,021	$185,376,799
2008	$36,587,339	$7,938,715,103	$291,353,888	$166,576,246	$24,318,988	$190,895,234
2009	$39,470,892	$8,310,962,138	$218,099,150	$169,164,572	$27,506,857	$196,671,429
2010	$41,734,378	$8,700,246,379	$233,759,453	$167,166,652	$35,417,388	$202,584,040
2011	$35,402,886	$9,103,949,481	$677,975,170	$168,284,732	$40,342,537	$208,627,269
2012	$32,842,569	$9,516,763,711	$1,012,920,355	$176,267,226	$38,599,410	$214,866,635
2013	$23,242,339	$9,965,970,563	$483,659,530	$177,218,705	$44,121,314	$221,340,019
2014	$21,122,412	$10,430,267,829	$770,214,885	$173,971,983	$53,994,906	$227,966,889
2015	$13,150,900	$10,937,223,141	$741,514,568	$207,507,628	$27,332,958	$234,840,585
2016	$7,803,454	$11,469,841,813	$505,931,517	$216,085,849	$25,818,622	$241,904,471
2017	$7,548,318	$12,033,844,058	$1,001,855,804	$235,157,531	$13,989,927	$249,147,458
2018	$6,218,569	$12,615,050,855	$1,349,179,096	$225,922,323	$30,651,332	$256,573,655
2019	$3,551,872	$13,232,392,055	$696,428,113	$256,688,747	$7,634,387	$264,323,134
2020	$3,990,216	$13,864,170,074	$1,574,797,121	$257,634,896	$14,472,055	$272,106,952
2021	$637,002	$14,512,140,104	$1,991,171,621	$262,031,489	$18,377,192	$280,408,681
2022	$716,061	$15,211,022,266	$1,823,343,527	$279,889,692	$8,922,563	$288,812,255
2023	$488,540	$15,948,788,015	$1,711,411,935	$277,049,461	$20,412,226	$297,461,687
2024	$537,517	$16,739,979,000	$1,041,091,939	$293,840,057	$12,572,306	$306,412,362
2025	$632,448	$17,540,176,989	$3,033,888,475	$301,930,835	$13,684,027	$315,614,862
Total	**$335,107,390**	**$232,883,828,042**	**$19,344,858,312**	**$4,320,204,065**	**$515,724,440**	**$4,835,928,505**

Table 66: Strategy 10 Condition 10% less – NBC Economic Impact Performance Measures

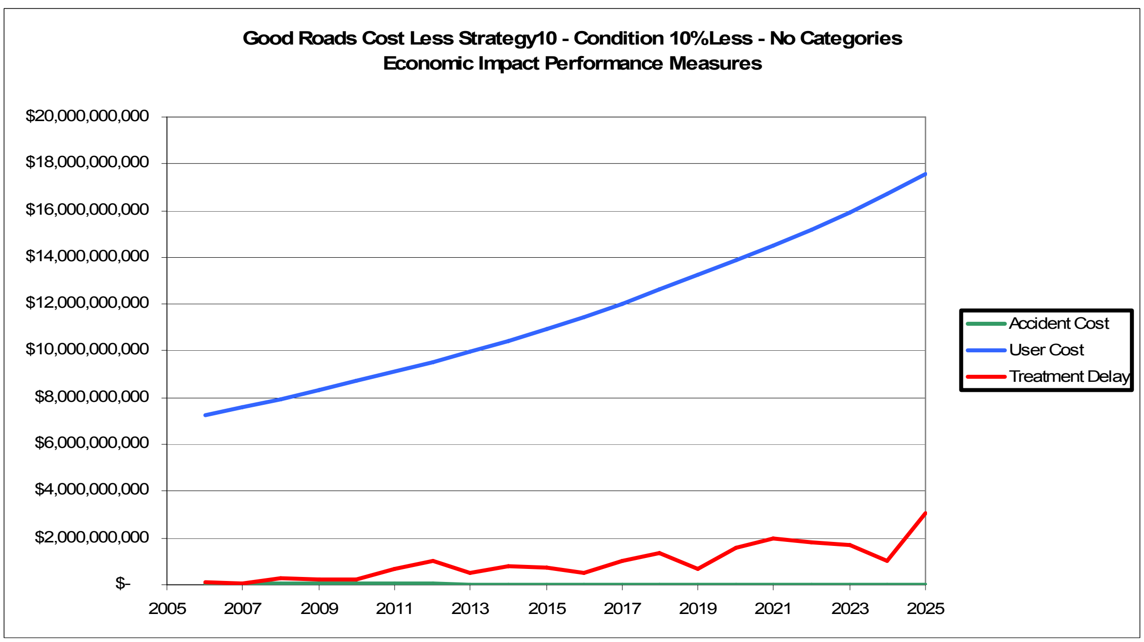


Figure 95: Strategy 10 Condition 10% less – NBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	154	99	71	0	342	71	3	1	6	4	**752**
2007	21	58	39	3	255	73	0	0	0	20	**469**
2008	9	106	25	10	272	59	6	0	6	18	**511**
2009	89	103	15	19	425	26	0	0	2	6	**686**
2010	79	135	1	15	454	20	0	0	0	0	**704**
2011	60	122	4	20	472	10	18	0	0	0	**707**
2012	101	111	63	4	487	16	14	0	0	0	**796**
2013	37	164	0	45	462	7	17	0	0	0	**731**
2014	249	152	21	60	350	2	5	0	0	0	**839**
2015	106	68	3	39	329	10	0	0	5	14	**573**
2016	23	59	12	107	230	1	11	0	13	2	**459**
2017	88	24	0	36	374	5	10	0	14	6	**558**
2018	106	101	0	14	535	10	4	0	1	2	**772**
2019	54	0	0	11	543	0	11	0	0	8	**627**
2020	140	0	0	9	546	0	12	0	5	4	**715**
2021	74	1	0	16	532	66	24	0	0	7	**720**
2022	63	0	0	5	552	94	10	1	0	0	**724**
2023	44	29	0	54	531	45	10	23	0	0	**736**
2024	66	10	0	93	408	26	9	18	0	0	**629**
2025	53	12	0	57	559	20	11	6	0	0	**719**
Total	**1617**	**1355**	**253**	**617**	**8658**	**558**	**177**	**48**	**52**	**90**	**13425**

Table 67: Strategy 10 Condition 10% less – NBC Treatment Distribution (miles)

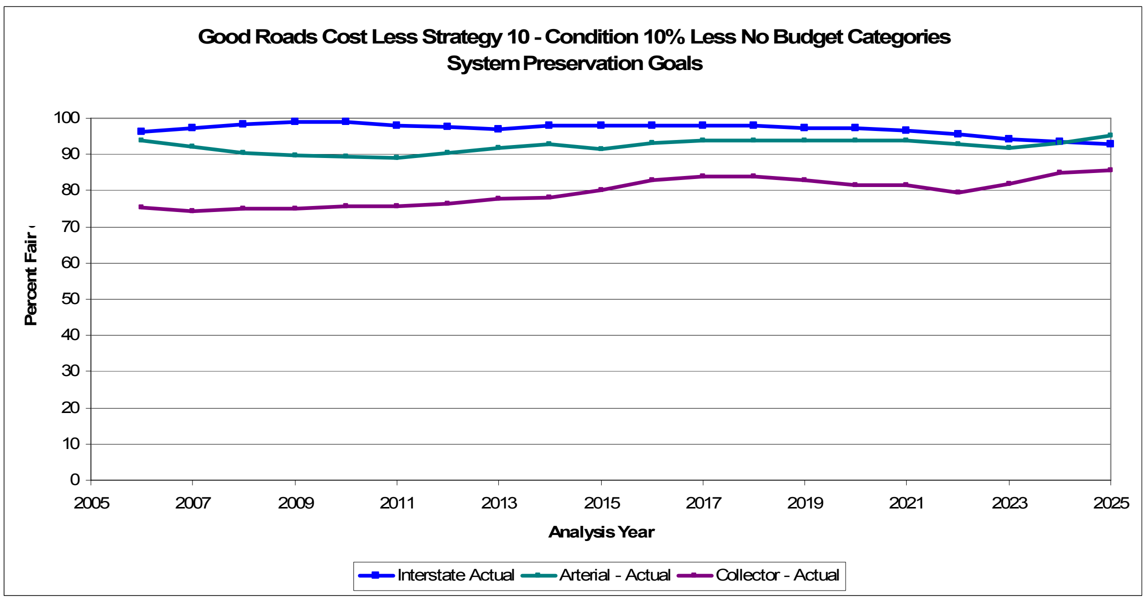


Figure 96: Strategy 10 Condition 10% less – NBC System Preservation Goal

5.3.16.2 Discussion

A 10% drop in condition of the UDOT Highway network sees the network overall condition stabilizes at approximately a level of 80 for OCI. The condition distribution of the OCI averages the percent of the network in good and excellent condition at 80% while the percent of the network in fair, poor and very poor average 20% throughout the analysis with some years approaching 25%.

The same amount of expenditure ($4.8 Billion) over the analysis period does not increase the OCI significantly to anywhere near to current levels. In order to significantly improve the network condition, a significant increase in minor maintenance and rehabilitation budgets would be required. This strategy illustrates the fact that if the condition of the network were to drop by 10% it would be very unlikely that UDOT could ever increase the condition of the network back to current condition levels as the increased level of funding would be difficult to achieve.

Other than the drop in condition for this strategy, the only other important factor to note is that the accident costs increased significantly over each of the previous strategies ($335 million compared to $112 million in the UDOT current model).

5.3.17 Strategy 10 – Condition 10% less -With Budget Categories

5.3.17.1 Results

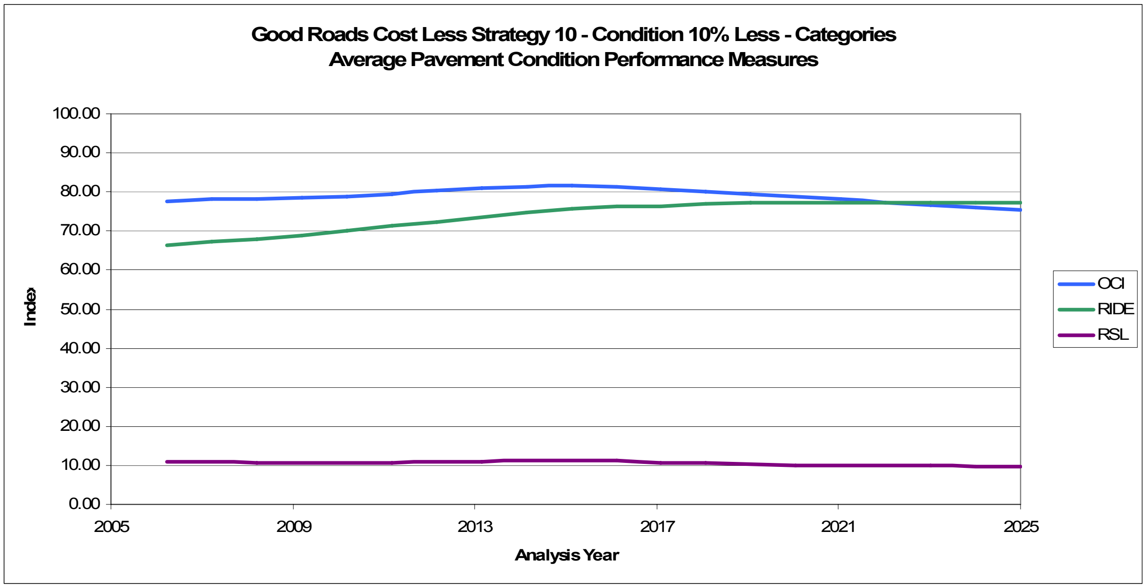


Figure 97: Strategy 10 Condition 10% less – WBC Condition Performance Measures

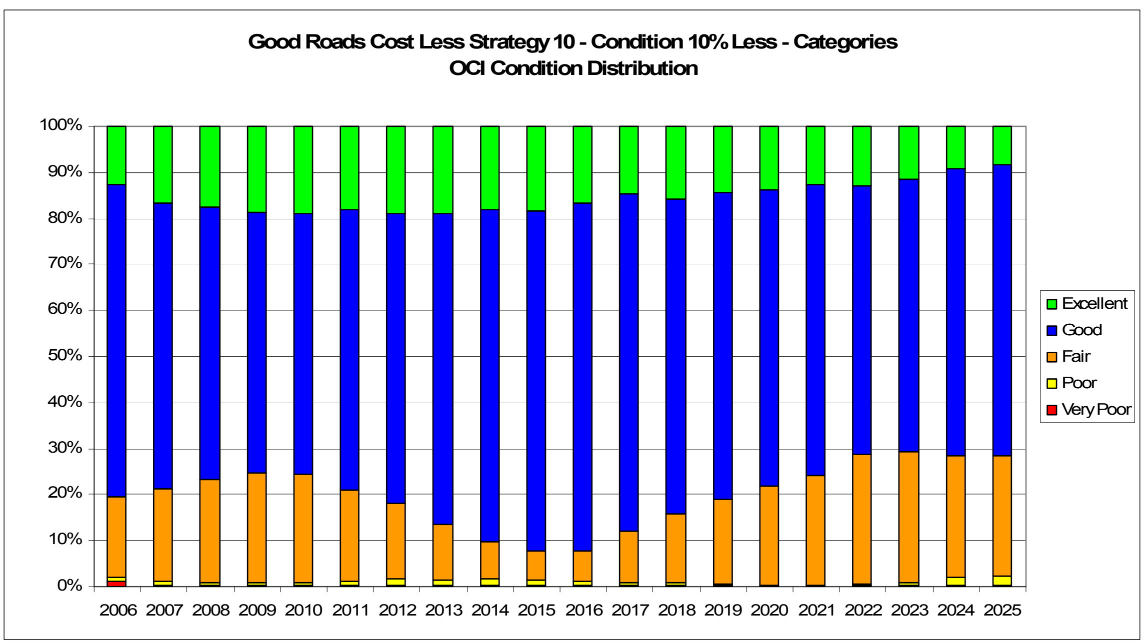


Figure 98: Strategy 10 Condition 10% less – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$28,877,674	$7,231,303,023	$129,199,154	$119,972,046	$59,782,978	$179,755,024
2007	$29,738,879	$7,580,402,319	$68,321,537	$123,585,922	$52,231,050	$175,816,972
2008	$36,058,926	$7,942,434,197	$285,509,651	$127,274,633	$37,553,012	$164,827,646
2009	$38,680,295	$8,316,821,656	$212,991,779	$130,965,262	$55,959,960	$186,925,222
2010	$41,560,856	$8,705,952,661	$233,960,929	$134,998,307	$67,468,400	$202,466,707
2011	$35,131,157	$9,108,140,197	$731,375,242	$138,931,690	$69,271,111	$208,202,802
2012	$28,830,861	$9,517,979,568	$1,146,012,109	$143,166,729	$71,517,290	$214,684,019
2013	$24,378,434	$9,967,742,630	$496,180,312	$147,578,820	$73,755,594	$221,334,414
2014	$17,934,013	$10,432,720,387	$563,335,886	$151,845,683	$75,645,918	$227,491,601
2015	$11,421,529	$10,944,622,464	$473,261,298	$156,552,039	$78,044,910	$234,596,949
2016	$6,588,190	$11,481,870,903	$587,350,647	$161,165,732	$46,978,495	$208,144,226
2017	$4,335,525	$12,049,465,850	$913,337,524	$166,068,560	$14,278,235	$180,346,795
2018	$3,023,660	$12,634,196,319	$1,334,804,226	$170,996,161	$15,512,293	$186,508,454
2019	$4,398,985	$13,262,875,369	$613,941,415	$176,207,189	$7,766,141	$183,973,330
2020	$4,037,287	$13,906,423,095	$1,817,966,327	$181,476,405	$16,247,078	$197,723,483
2021	$242,804	$14,557,244,771	$2,248,938,464	$186,925,089	$15,042,387	$201,967,476
2022	$281,237	$15,266,173,742	$1,886,933,889	$192,547,815	$8,746,215	$201,294,030
2023	$324,618	$16,014,533,873	$1,571,541,971	$198,338,703	$11,773,487	$210,112,190
2024	$373,541	$16,814,012,110	$932,872,271	$204,249,034	$9,503,488	$213,752,522
2025	$446,800	$17,630,872,073	$2,020,780,257	$210,334,727	$5,576,381	$215,911,108
Total	**$316,665,272**	**$233,365,787,207**	**$18,268,614,889**	**$3,223,180,545**	**$792,654,424**	**$4,015,834,969**

Table 68: Strategy 10 Condition 10% less – WBC Economic Impact Performance Measures

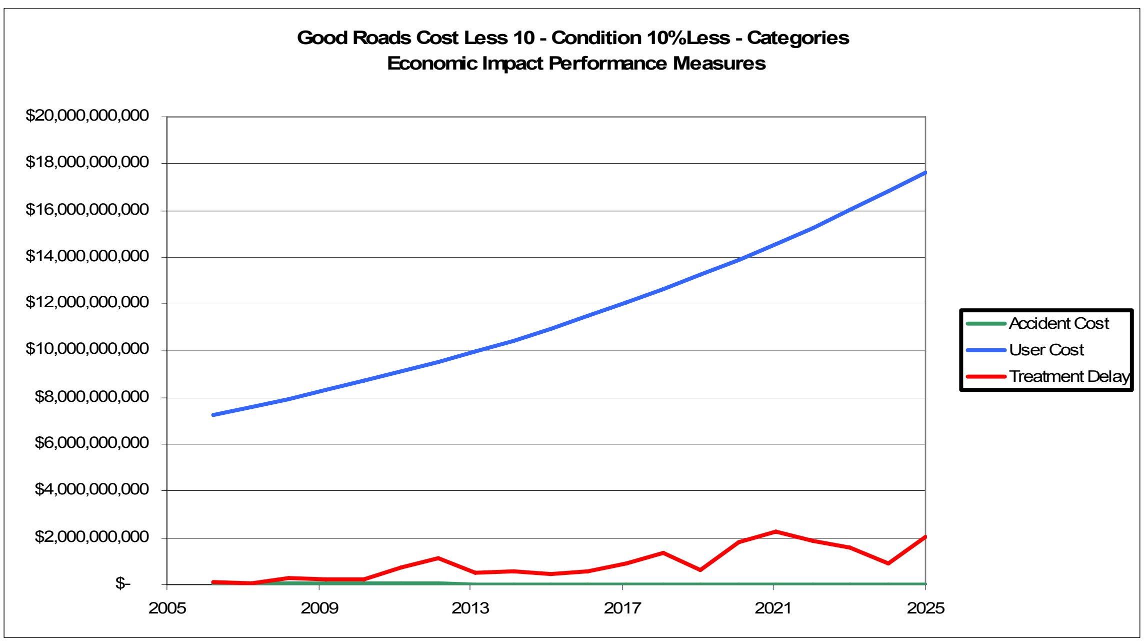


Figure 99: Strategy 10 Condition 10% less – WBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	152	210	76	0	263	82	3	1	6	1	**795**
2007	21	205	39	15	248	61	0	0	2	3	**594**
2008	9	170	12	0	187	59	6	0	0	19	**463**
2009	81	225	29	20	251	26	0	0	0	10	**641**
2010	77	247	1	12	380	20	0	0	0	0	**735**
2011	37	279	16	12	388	10	21	0	0	0	**764**
2012	101	268	59	7	346	16	14	0	0	0	**811**
2013	17	293	0	33	395	7	15	0	0	0	**760**
2014	241	223	21	37	309	2	13	0	0	0	**846**
2015	166	231	3	36	305	10	0	0	4	7	**761**
2016	18	149	12	43	255	1	11	0	5	8	**502**
2017	85	15	4	12	252	5	10	0	2	13	**397**
2018	173	9	0	32	371	10	4	0	0	2	**601**
2019	57	0	0	5	386	0	11	0	8	0	**467**
2020	168	0	0	20	352	0	12	0	0	3	**554**
2021	119	0	0	9	314	78	15	0	0	4	**539**
2022	27	0	0	5	332	82	13	1	0	0	**460**
2023	49	0	0	24	357	45	13	3	0	0	**491**
2024	45	0	0	46	348	26	9	19	0	0	**492**
2025	17	0	0	15	472	20	7	10	0	0	**540**
Total	**1658**	**2523**	**273**	**382**	**6511**	**558**	**178**	**34**	**27**	**70**	**12213**

Table 69: Strategy 10 Condition 10% less – WBC Treatment Distribution (miles)

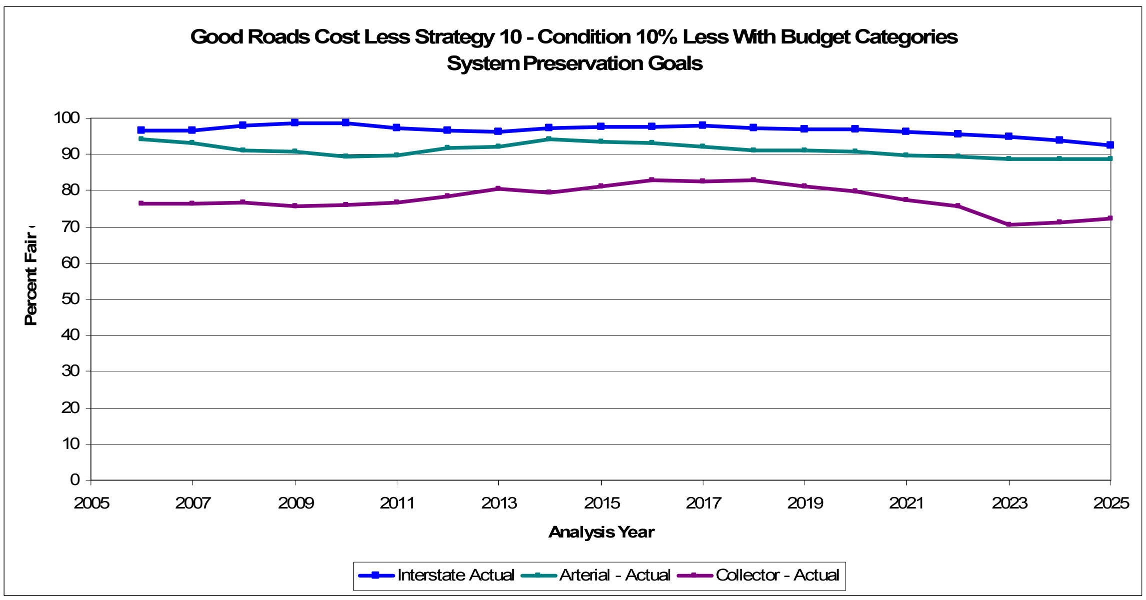


Figure 100: Strategy 10 Condition 10% less – WBC System Preservation Goals

5.3.17.2 Discussion

The influence of the budget categories (Orange book and Blue book) within this strategy causes the condition to deteriorate and not recover during the analysis to the starting condition.

There is an increase in accident costs of $317 million which is less when compared to the increase of $335 Million in the previous strategy with more Orange book projects being programmed due to the fixed Orange Book budget.

The condition of the network continues to deteriorate within this strategy as the fixed Orange Book and Blue Book budgets are not able to account for the deterioration and the 10% drop in condition. This strategy again illustrates the fact that if the condition of the network were to drop by 10% it would be very unlikely that UDOT could ever increase the condition of the network back to current condition levels as the increased level of funding would be difficult to achieve.

5.3.18 Strategy 11 – Condition 20% less -No Budget Categories

5.3.18.1 Results

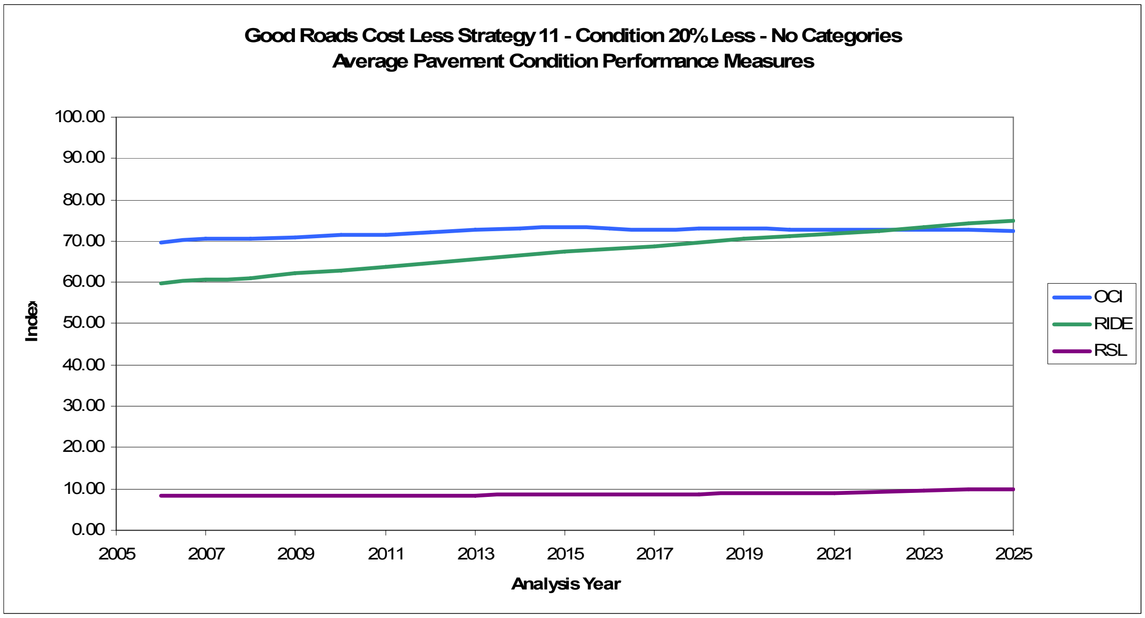


Figure 101: Strategy 11 Condition 20% less – NBC Performance Measures

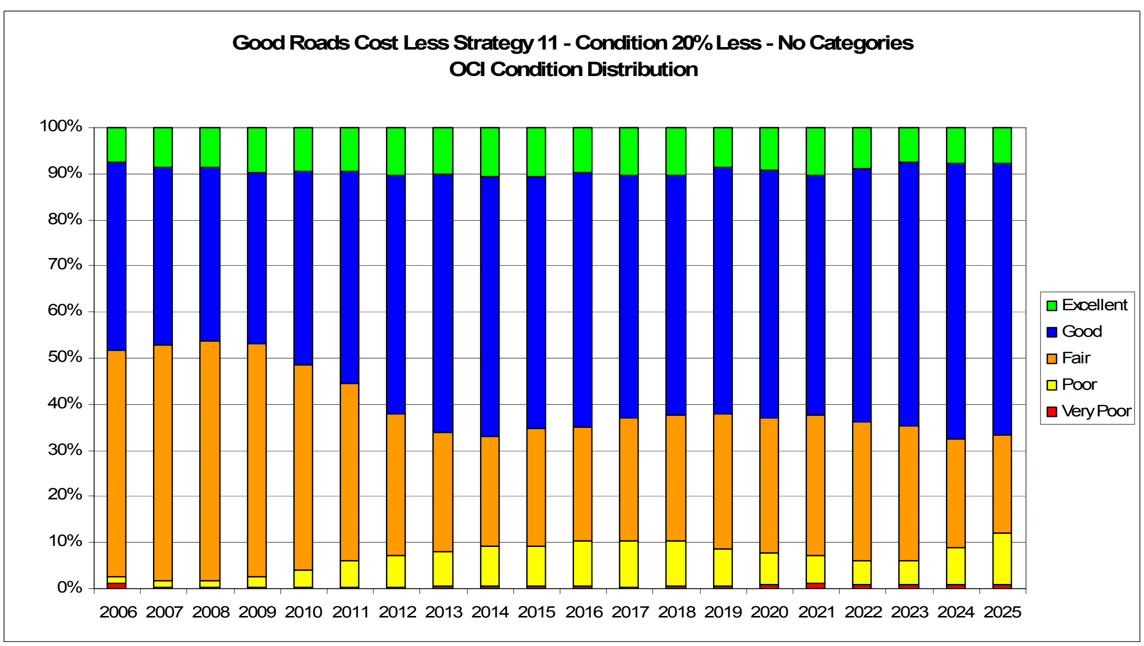


Figure 102: Strategy 11 Condition 20% less – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$89,584,532	$7,326,536,177	$102,400,416	$166,435,297	$13,535,905	$179,971,202
2007	$97,706,302	$7,678,057,127	$67,219,606	$162,581,760	$22,752,307	$185,334,068
2008	$111,415,918	$8,044,214,529	$277,218,018	$168,409,920	$22,521,959	$190,931,879
2009	$120,066,218	$8,416,503,913	$181,173,054	$171,749,651	$24,892,770	$196,642,421
2010	$118,997,331	$8,807,955,720	$268,229,536	$164,045,428	$38,530,876	$202,576,305
2011	$108,281,072	$9,199,548,020	$983,396,441	$163,961,553	$44,691,913	$208,653,466
2012	$76,455,474	$9,612,241,841	$951,370,174	$177,275,657	$37,623,551	$214,899,208
2013	$49,925,795	$10,034,696,724	$1,283,759,782	$167,744,397	$53,625,003	$221,369,400
2014	$40,531,301	$10,518,282,362	$398,870,378	$183,951,877	$44,003,940	$227,955,817
2015	$33,155,698	$11,034,809,302	$515,125,353	$186,555,573	$48,250,571	$234,806,144
2016	$24,906,995	$11,572,759,598	$648,317,256	$234,402,409	$7,400,683	$241,803,092
2017	$22,176,388	$12,129,641,768	$756,095,711	$234,039,531	$15,069,540	$249,109,071
2018	$19,670,547	$12,700,865,311	$1,401,789,726	$241,065,352	$15,477,384	$256,542,737
2019	$11,699,307	$13,314,612,762	$676,058,299	$234,270,264	$29,988,677	$264,258,941
2020	$10,330,308	$13,958,485,346	$1,230,708,012	$257,144,217	$15,114,335	$272,258,552
2021	$7,078,313	$14,614,489,844	$2,897,045,255	$268,059,642	$12,290,942	$280,350,584
2022	$3,081,747	$15,334,034,277	$1,565,489,375	$249,522,477	$39,303,938	$288,826,415
2023	$2,751,533	$16,085,548,717	$1,513,841,503	$272,676,394	$24,833,678	$297,510,072
2024	$2,880,649	$16,878,131,741	$1,985,359,719	$291,817,269	$14,547,290	$306,364,558
2025	$3,183,135	$17,674,699,616	$1,331,696,027	$309,475,158	$6,104,917	$315,580,075
Total	**$953,878,563**	**$234,936,114,696**	**$19,035,163,640**	**$4,305,183,825**	**$530,560,181**	**$4,835,744,005**

Table 70: Strategy 11 Condition 20% less – NBC Economic Impact Performance Measures

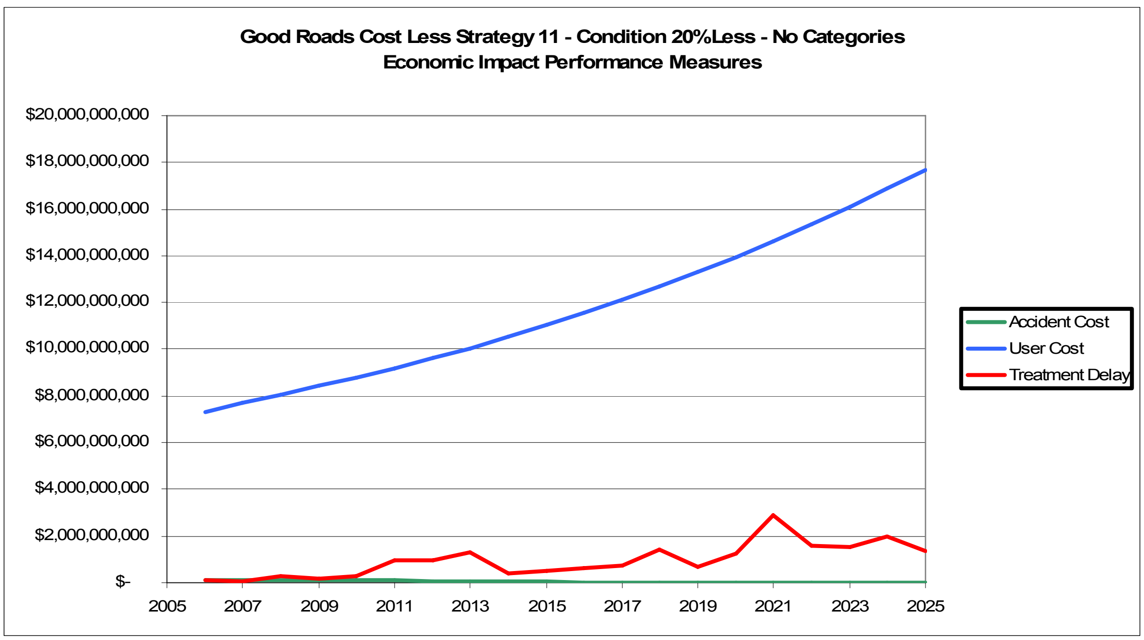


Figure 103: Strategy 11 Condition 20% less – NBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	41	48	115	1	331	85	0	0	4	1	**627**
2007	0	97	45	8	412	35	0	0	2	3	**602**
2008	0	113	20	15	234	19	5	0	4	25	**436**
2009	35	92	25	42	384	16	0	0	0	1	**596**
2010	24	134	20	33	375	0	0	0	0	1	**589**
2011	9	175	7	25	335	6	11	0	5	6	**579**
2012	19	120	45	7	456	13	12	0	0	0	**672**
2013	10	188	13	52	331	6	2	0	0	5	**609**
2014	13	157	24	84	306	0	5	0	0	0	**589**
2015	16	206	0	64	353	6	5	0	2	2	**654**
2016	20	28	12	62	260	0	9	0	0	24	**415**
2017	76	43	4	23	335	5	6	0	8	15	**513**
2018	45	61	0	62	410	10	2	0	0	4	**593**
2019	16	124	0	51	405	0	10	0	0	12	**618**
2020	30	42	0	90	340	0	4	0	8	0	**514**
2021	45	37	0	70	306	74	4	0	0	9	**545**
2022	3	152	0	87	359	34	2	0	0	0	**636**
2023	5	69	0	96	446	22	8	5	0	0	**651**
2024	19	25	0	160	309	20	4	25	0	0	**562**
2025	8	16	0	72	482	10	3	1	0	0	**592**
Total	**435**	**1928**	**329**	**1105**	**7169**	**361**	**93**	**31**	**33**	**108**	**11593**

Table 71: Strategy 11 Condition 20% less – NBC Treatment Distribution (miles)

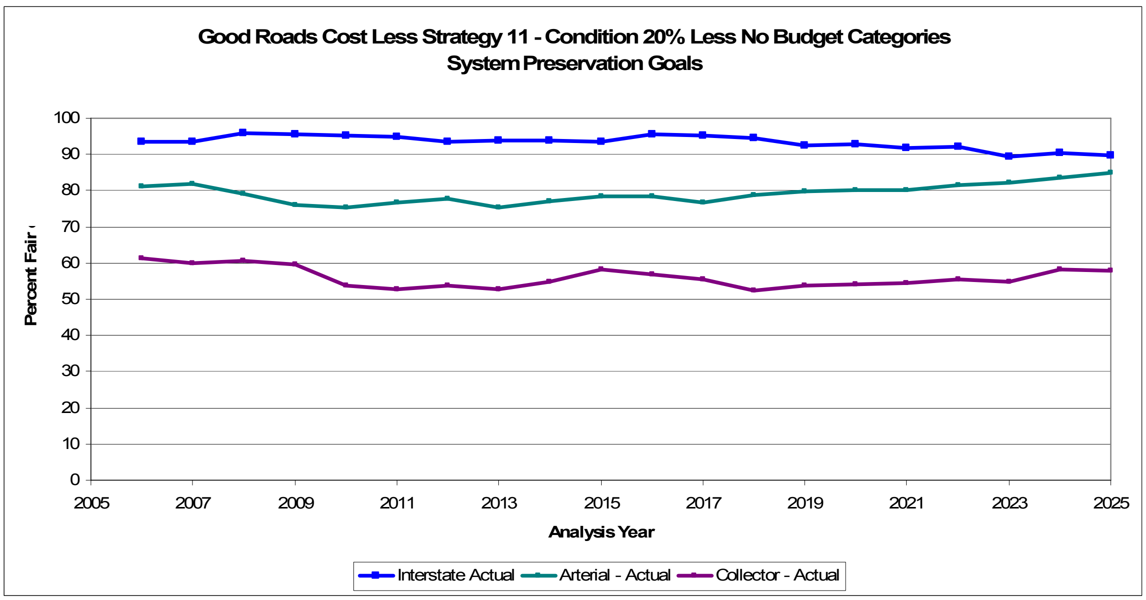


Figure 104: Strategy 11 Condition 20% less – NBC System Preservation Goals

5.3.18.2 Discussion

A twenty percent reduction in condition for the UDOT highway network would result in a very different network than that of today.   More than 50% of the highway network would be in fair or worse condition at the start of the analysis and the percentage would be slowly reduced to just more than 30% within the analysis period.

Increased accident costs would approach $1 billion due to the reduction in skid numbers throughout the network. User costs would be the highest of any of the normal strategies (Strategies 4 though 10) and the overall condition at the end of the analysis would be the lowest.

With no budget category restrictions, there is a slight rise in the overall condition of the network (OCI) and a slight rise in the RSL over the analysis, but that trend would quickly change as the percent in the very poor and poor categories continues to increase.

In fact, after the initial period of the analysis, the excellent and good roads appear to be maintained by the system while the fair, poor and very poor roads continue to deteriorate. The optimization can no longer afford to program heavy rehabilitation and reconstruction on the poor and very poor roads so they are left to deteriorate while the excellent and good roads are maintained and the fair roads are rehabilitated slowly as money becomes available. Within this strategy, maintaining the good roads at the expense of the fair or worse roads is the only alternative.

5.3.19 Strategy 11 – Condition 20% less -With Budget Categories

5.3.19.1 Results

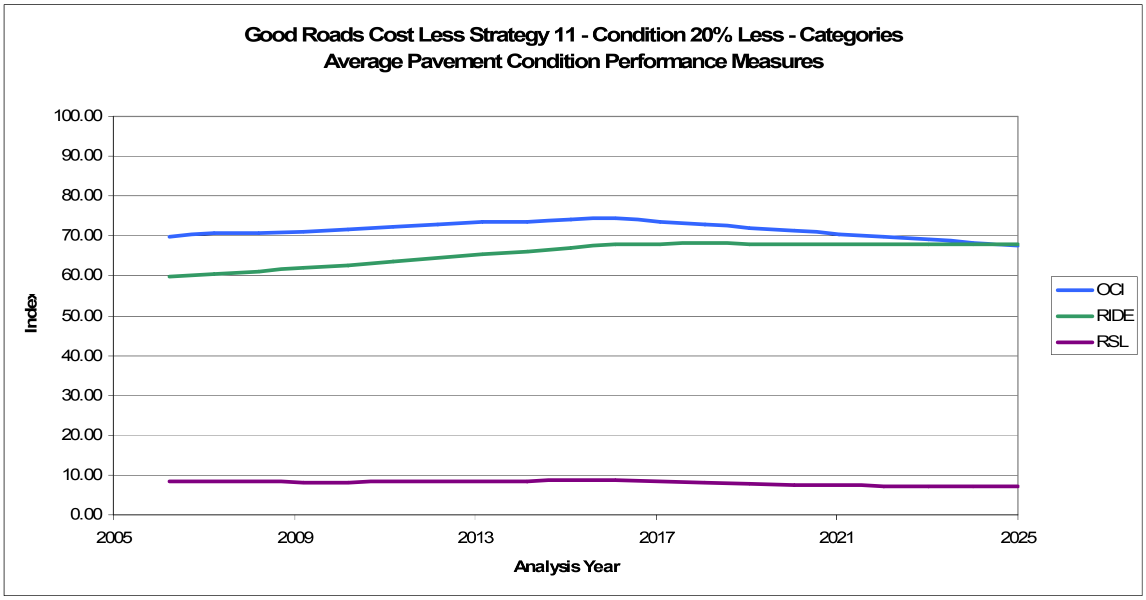


Figure 105: Strategy 11 Condition 20% less – WBC Condition Performance Measures

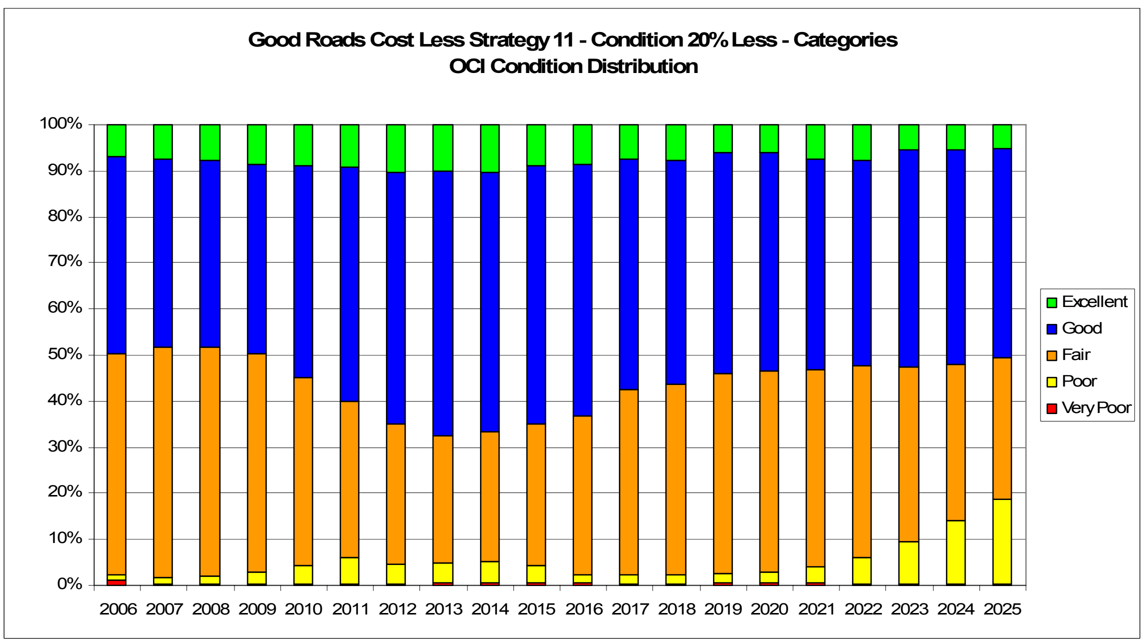


Figure 106: Strategy 11 Condition 20% less – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$91,103,753	$7,329,456,919	$98,682,475	$119,991,929	$59,494,261	$179,486,190
2007	$99,298,396	$7,684,684,940	$53,868,517	$123,588,903	$46,197,117	$169,786,019
2008	$111,279,743	$8,051,410,805	$285,071,718	$127,235,538	$34,665,026	$161,900,563
2009	$120,823,510	$8,426,664,675	$177,934,063	$131,068,279	$64,984,738	$196,053,017
2010	$118,233,674	$8,823,571,860	$259,994,887	$134,997,580	$67,442,407	$202,439,987
2011	$109,577,929	$9,221,262,107	$719,824,904	$139,084,822	$69,358,709	$208,443,531
2012	$83,475,291	$9,644,350,489	$947,850,240	$143,264,065	$71,619,018	$214,883,083
2013	$54,666,942	$10,075,018,567	$1,065,940,984	$147,562,041	$73,609,226	$221,171,267
2014	$35,264,066	$10,537,279,811	$1,011,902,421	$151,993,175	$75,781,392	$227,774,567
2015	$27,781,161	$11,053,760,860	$403,750,599	$156,460,896	$78,120,410	$234,581,306
2016	$26,931,394	$11,607,362,344	$366,653,310	$161,193,791	$80,406,231	$241,600,022
2017	$25,600,594	$12,174,249,645	$613,261,262	$166,049,283	$15,871,737	$181,921,020
2018	$22,626,442	$12,752,094,303	$1,732,906,038	$170,996,561	$3,019,672	$174,016,233
2019	$18,202,213	$13,369,428,283	$1,075,224,248	$176,173,927	$4,241,481	$180,415,407
2020	$14,710,894	$14,026,313,182	$902,668,549	$181,510,183	$3,524,818	$185,035,001
2021	$17,096,530	$14,693,522,655	$2,348,224,403	$186,914,868	$5,848,235	$192,763,103
2022	$9,058,035	$15,406,949,908	$2,120,042,853	$192,545,225	$1,337,257	$193,882,483
2023	$6,788,465	$16,170,045,007	$1,632,679,017	$198,331,039	$1,264,232	$199,595,271
2024	$7,702,060	$16,971,840,769	$1,633,917,832	$204,291,008	$4,368,435	$208,659,443
2025	$8,727,623	$17,792,682,894	$1,211,363,070	$210,414,445	$1,027,842	$211,442,287
Total	**$1,008,948,717**	**$235,811,950,023**	**$18,661,761,391**	**$3,223,667,558**	**$762,182,241**	**$3,985,849,799**

Table 72: Strategy 11 Condition 20% less – WBC Economic Impact Performance Measures

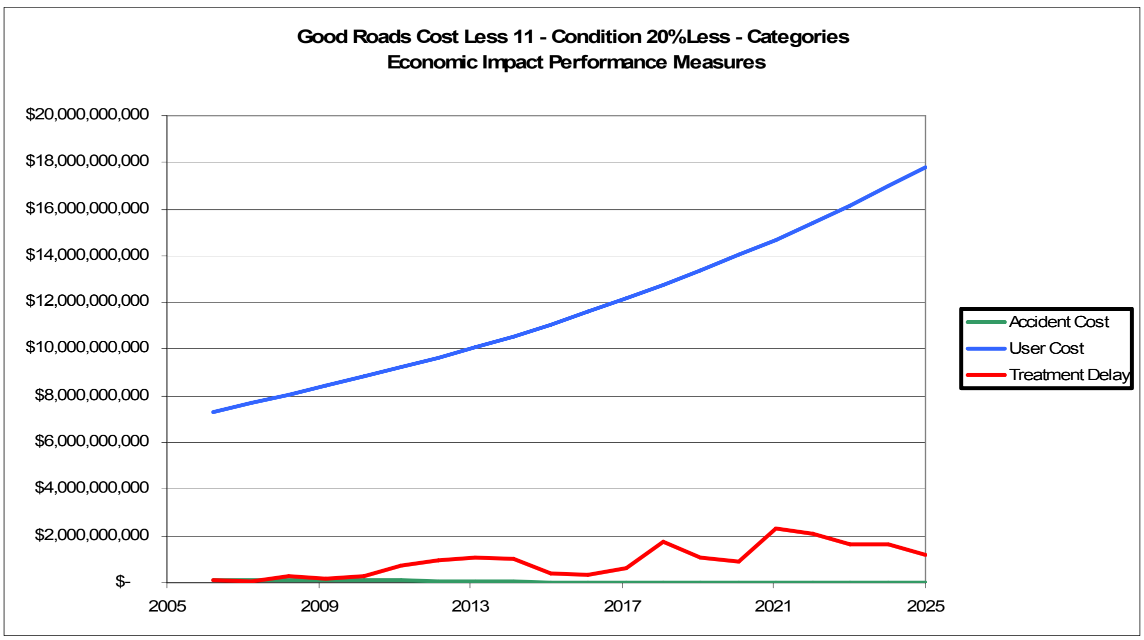


Figure 107: Strategy 11 Condition 20% less – WBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	36	272	109	0	221	85	0	0	4	1	**728**
2007	0	207	59	9	270	35	0	0	2	0	**582**
2008	0	177	20	9	301	27	5	0	0	3	**542**
2009	35	246	25	45	251	8	0	0	0	1	**611**
2010	24	246	20	21	322	0	0	0	0	1	**635**
2011	5	311	7	28	307	6	11	0	0	0	**675**
2012	12	344	50	7	316	13	12	0	0	0	**754**
2013	10	290	13	35	281	6	2	0	0	5	**643**
2014	12	311	24	52	203	0	5	0	5	6	**619**
2015	9	327	0	49	298	6	5	0	4	0	**699**
2016	17	345	12	42	269	0	10	0	0	12	**706**
2017	85	5	4	0	248	3	6	0	0	17	**368**
2018	42	0	0	17	330	11	2	0	2	4	**408**
2019	21	0	0	3	272	0	10	0	0	14	**320**
2020	30	0	0	61	224	0	4	0	0	10	**328**
2021	32	0	0	31	292	74	10	0	0	0	**439**
2022	0	0	0	51	277	34	2	1	0	4	**371**
2023	8	0	0	40	334	30	3	0	0	3	**417**
2024	10	0	0	55	324	12	9	3	0	0	**414**
2025	4	0	0	64	329	10	2	1	0	0	**410**
Total	**393**	**3080**	**343**	**620**	**5669**	**361**	**97**	**6**	**17**	**82**	**10668**

Table 73: Strategy 11 Condition 20% less – WBC Treatment Distribution (miles)

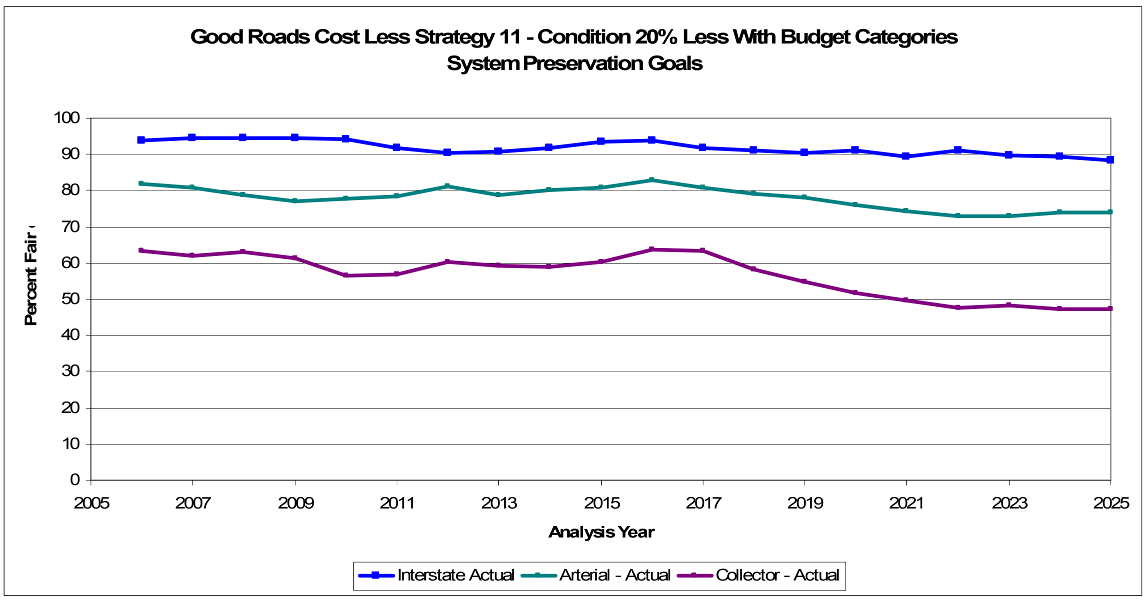


Figure 108: Strategy 11 Condition 20% less – WBC System Preservation Goals

5.3.19.2 Discussion

As was seen in the previous strategy, the 20% reduction in the network condition changes the UDOT network quite substantially. This network change is amplified greatly by the fixed Orange book and Blue book budget categories.

With a reduction in the network condition of 20%, many segments in the network leave the treatment trigger ranges for minor maintenance treatments and enter the rehabilitation category where only minor rehabilitations, major rehabilitations and complete reconstructions are the only alternatives. This lack of segments in the minor maintenance category causes this strategy to spend approximately $850 million less than the unrestricted strategy with no budget categories. Simply put, there is not enough money in the Blue book program to rehabilitate enough miles of pavement to improve the condition and there are not enough segments in the good and excellent condition to spend all of the Orange book money.

This strategy results in the lowest overall condition and RSL of all the normal strategies (4 through 10) and results in the highest increased accident costs and user costs of those strategies.

5.3.20 Strategy 12 – No Funding 5 Years -No Budget Categories

5.3.20.1 Results

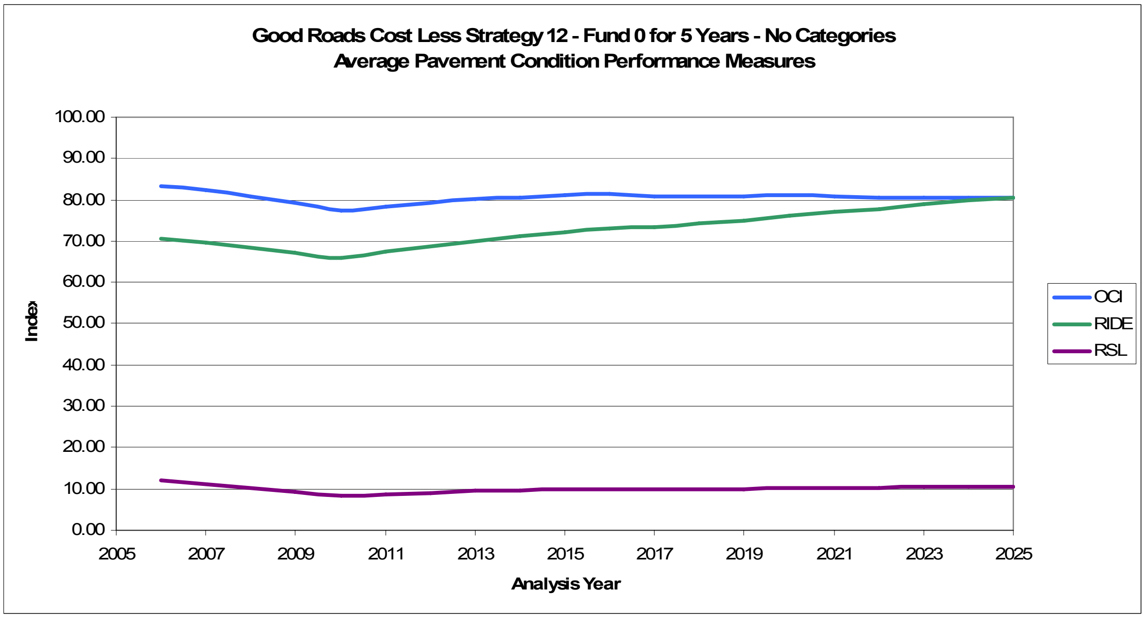


Figure 109: Strategy 12 No Funding 5 Years – NBC Condition Performance Measures

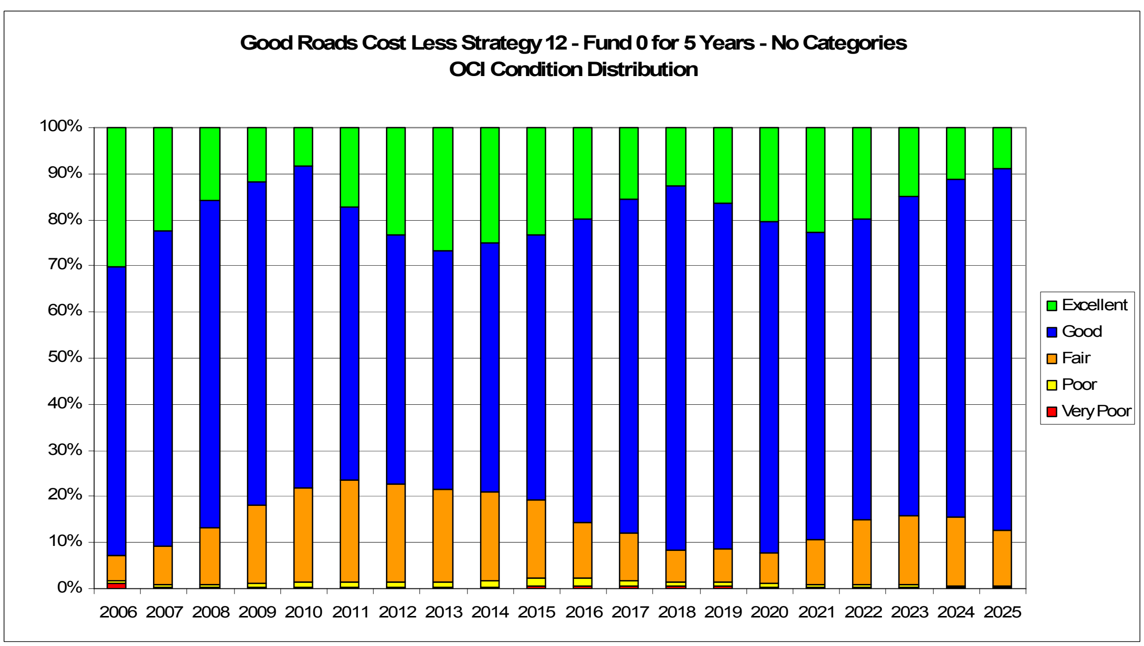


Figure 110: Strategy 12 No Funding 5 Years – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$14,159,961	$7,174,251,886	$0	$0	$0	$0
2007	$16,351,546	$7,549,730,805	$0	$0	$0	$0
2008	$19,535,999	$7,945,637,395	$0	$0	$0	$0
2009	$24,113,494	$8,363,058,951	$0	$0	$0	$0
2010	$28,959,407	$8,803,204,952	$0	$0	$0	$0
2011	$30,514,295	$9,168,926,038	$963,027,872	$85,953,470	$122,715,736	$208,669,206
2012	$28,176,076	$9,578,943,032	$605,895,661	$104,310,807	$110,587,743	$214,898,550
2013	$26,744,103	$10,019,823,131	$623,818,773	$117,239,454	$104,133,578	$221,373,032
2014	$20,372,063	$10,481,699,510	$767,919,414	$149,604,929	$78,354,269	$227,959,198
2015	$10,779,928	$10,980,450,482	$939,986,463	$166,346,727	$68,473,220	$234,819,948
2016	$10,517,781	$11,529,104,899	$120,507,504	$207,846,428	$34,021,066	$241,867,494
2017	$8,115,301	$12,094,350,147	$981,793,866	$215,321,832	$33,825,305	$249,147,137
2018	$6,801,000	$12,683,868,584	$2,491,013,068	$244,132,838	$12,480,577	$256,613,415
2019	$7,145,968	$13,286,990,979	$1,170,120,981	$245,327,604	$18,863,157	$264,190,761
2020	$4,467,404	$13,937,969,817	$1,034,909,816	$248,820,248	$23,433,497	$272,253,745
2021	$2,366,385	$14,594,983,350	$2,095,791,911	$261,825,312	$18,561,287	$280,386,599
2022	$1,297,743	$15,291,984,331	$2,813,884,834	$280,679,992	$8,129,328	$288,809,320
2023	$1,302,960	$16,044,538,380	$765,524,677	$280,749,411	$16,749,756	$297,499,167
2024	$566,057	$16,837,489,562	$311,424,897	$291,343,335	$15,036,531	$306,379,866
2025	$637,974	$17,657,420,076	$287,455,862	$307,861,102	$7,739,457	$315,600,559
Total	**$262,925,447**	**$234,024,426,308**	**$15,973,075,599**	**$3,207,363,489**	**$673,104,509**	**$3,880,467,998**

Table 74: Strategy 12 No Funding 5 Years – NBC Economic Impact Performance Measures

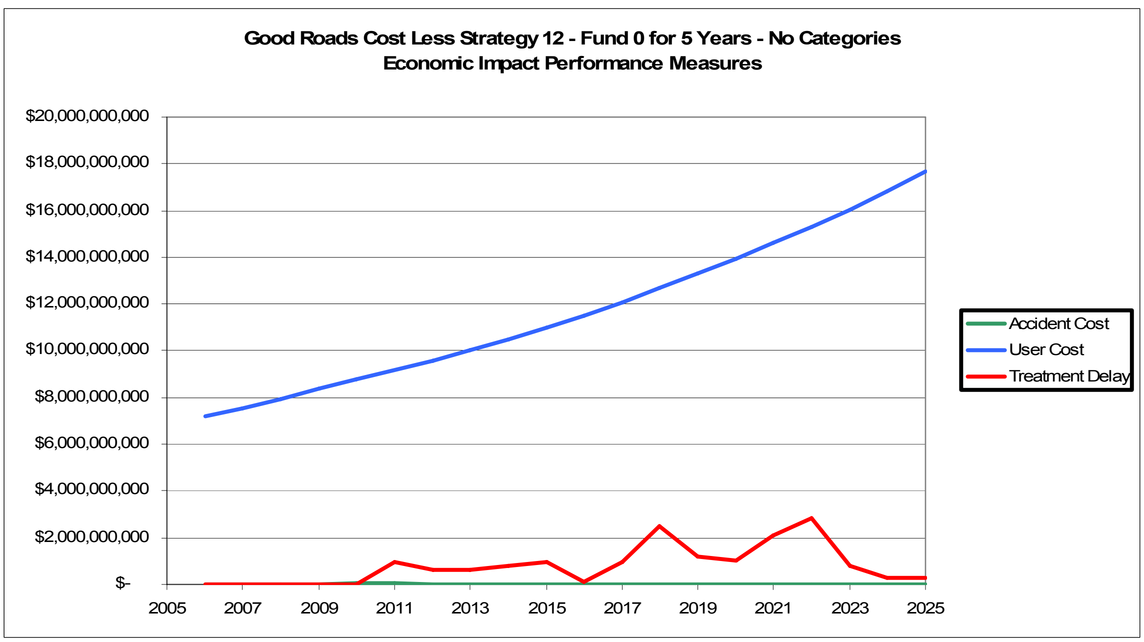


Figure 111: Strategy 12 No Funding 5 Years – NBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	0	0	0	0	0	0	0	0	0	0	**0**
2007	0	0	0	0	0	0	0	0	0	0	**0**
2008	0	0	0	0	0	0	0	0	0	0	**0**
2009	0	0	0	0	0	0	0	0	0	0	**0**
2010	0	0	0	0	0	0	0	0	0	0	**0**
2011	453.15	343.598	88.789	0.37	171.407	44.281	14.649	0	3.991	0	**1120**
2012	341.528	339.774	35.5	0	268.874	61.402	24.538	0	0	0	**1072**
2013	247.752	346.554	43.41	2.978	288.795	26.281	11.421	0	0	0	**967**
2014	68.912	260.631	23.87	5.63	350.19	48.766	14.008	0	0	0	**772**
2015	73.154	234.638	11.404	4.305	409.841	51.67	10.231	0	0	0.864	**796**
2016	0	116.379	56.856	8.736	423.219	12.845	2.131	0	3.36	12.687	**636**
2017	0	91.809	20.27	14.348	230.621	27.939	10.041	0	0	32.174	**427**
2018	0	59.107	0	44.934	380.728	19.628	0	0	0	14.54	**519**
2019	135.513	11.98	0	26.913	459.714	0.099	18.338	0	17.021	0	**670**
2020	245.532	17.002	0	31.715	547.905	5.305	4.109	0	6.079	0	**858**
2021	98.802	4.186	0	0	631.147	0	15.164	0	0	7.028	**756**
2022	48.851	0	0	35.549	513.175	0	10.372	0	8.131	1.856	**618**
2023	55.489	0	0	39.29	615.983	0	28.302	0	0	0	**739**
2024	38.354	33.066	0	66.633	533.047	3.406	5.929	0	0	0	**680**
2025	13.087	12.451	0	61.901	560.44	0	10.402	0	0	0	**658**
Total	**1820**	**1871**	**280**	**343**	**6385**	**302**	**180**	**0**	**39**	**69**	**11289**

Table 75: Strategy 12 No Funding 5 Years – NBC Treatment Distribution (miles)

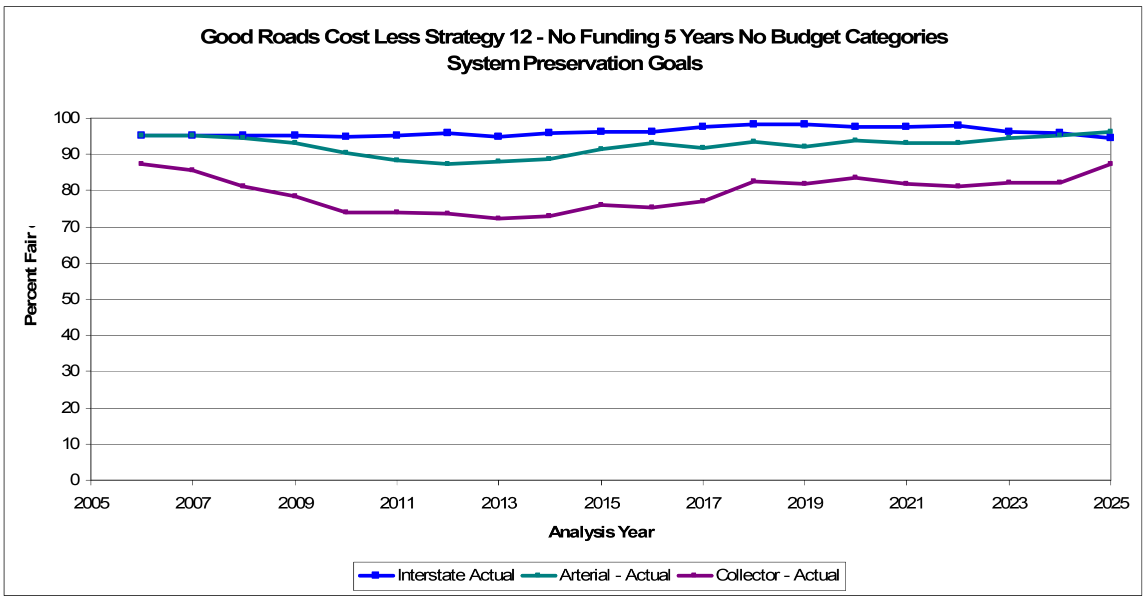


Figure 112: Strategy 12 No Funding 5 Years – NBC System Preservation Goals

5.3.20.2 Discussion

The No Funding strategy for 5 years was included in the analysis to demonstrate the affects on the UDOT highway network if the maintenance and preservation funding was eliminated to help build new and enhance existing capacity throughout the network.

As could be expected with this scenario, accident and user costs increase quite dramatically as the condition of the network deteriorates during the initial analysis period with no funding.

Following that initial period of deterioration the network never returns to the original condition levels at the start of the analysis.

5.3.21 Strategy 12 – No Funding 5 Years -With Budget Categories

5.3.21.1 Results

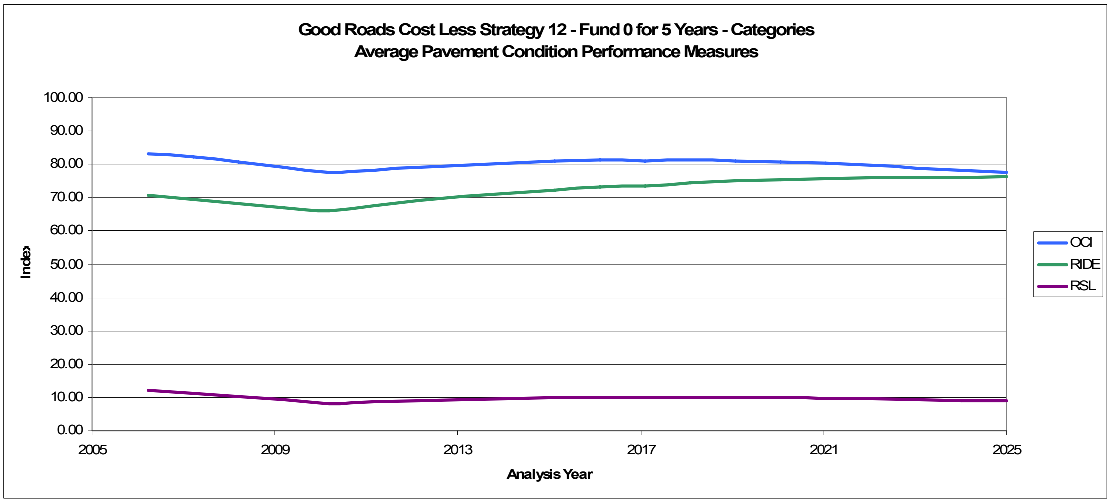


Figure 113: Strategy 12 No Funding 5 Years – WBC Condition Performance Measures

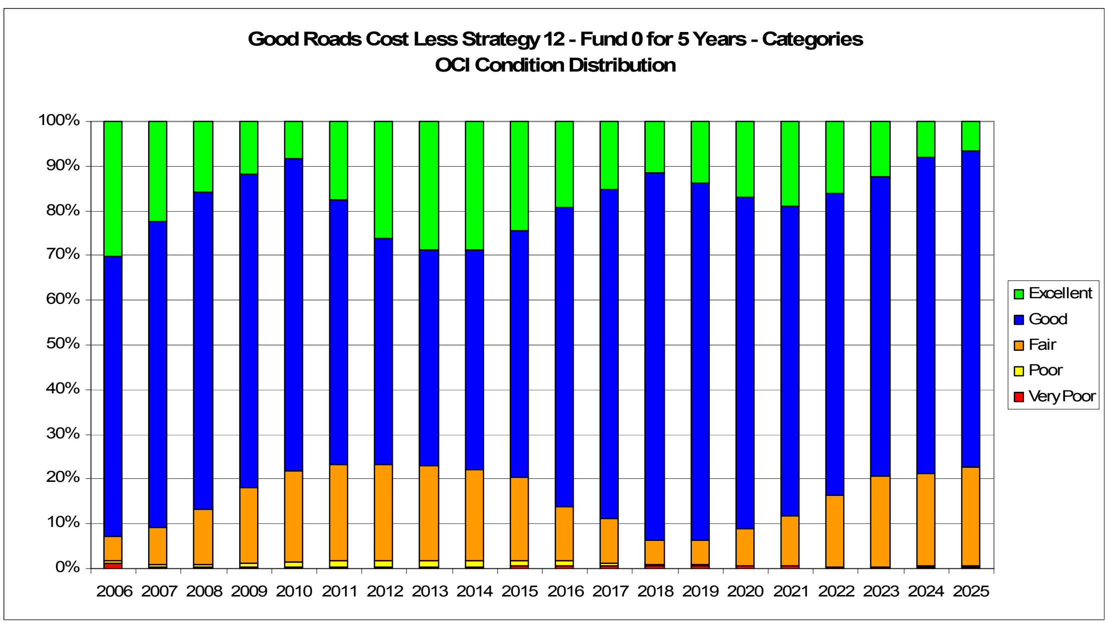


Figure 114: Strategy 12 No Funding 5 Years – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$14,159,961	$7,174,251,886	$0	$0	$0	$0
2007	$16,351,546	$7,549,730,805	$0	$0	$0	$0
2008	$19,535,999	$7,945,637,395	$0	$0	$0	$0
2009	$24,113,494	$8,363,058,951	$0	$0	$0	$0
2010	$28,959,407	$8,803,204,952	$0	$0	$0	$0
2011	$29,391,689	$9,169,973,633	$958,104,372	$139,100,431	$69,554,870	$208,655,301
2012	$29,829,087	$9,579,301,367	$590,302,390	$143,254,989	$71,603,741	$214,858,730
2013	$27,954,482	$10,019,839,708	$641,181,699	$147,512,424	$73,718,576	$221,231,000
2014	$24,049,903	$10,479,054,751	$776,360,469	$151,963,619	$75,992,195	$227,955,814
2015	$15,833,895	$10,972,655,178	$968,922,921	$156,465,437	$78,252,813	$234,718,250
2016	$15,013,549	$11,522,680,711	$114,455,759	$161,251,199	$80,577,836	$241,829,035
2017	$11,949,435	$12,091,663,018	$967,632,989	$165,997,069	$83,006,354	$249,003,422
2018	$6,972,525	$12,679,176,504	$2,508,689,270	$171,073,408	$85,534,199	$256,607,607
2019	$7,342,392	$13,297,307,955	$1,086,100,297	$176,126,631	$72,199,283	$248,325,914
2020	$3,963,940	$13,947,763,069	$1,105,833,153	$181,459,170	$35,864,542	$217,323,712
2021	$1,940,955	$14,609,484,807	$2,088,549,371	$186,945,683	$22,449,027	$209,394,710
2022	$817,448	$15,309,479,875	$2,868,253,726	$192,482,575	$11,425,643	$203,908,219
2023	$916,214	$16,074,707,508	$518,636,332	$198,337,004	$11,974,829	$210,311,833
2024	$222,743	$16,877,098,605	$281,324,716	$204,280,939	$7,505,839	$211,786,778
2025	$260,523	$17,703,870,267	$237,154,226	$210,408,253	$6,166,019	$216,574,272
Total	**$279,579,190**	**$234,169,940,944**	**$15,711,501,690**	**$2,586,658,833**	**$785,825,765**	**$3,372,484,597**

Table 76: Strategy 12 No Funding 5 Years – WBC Economic Impact Performance Measures

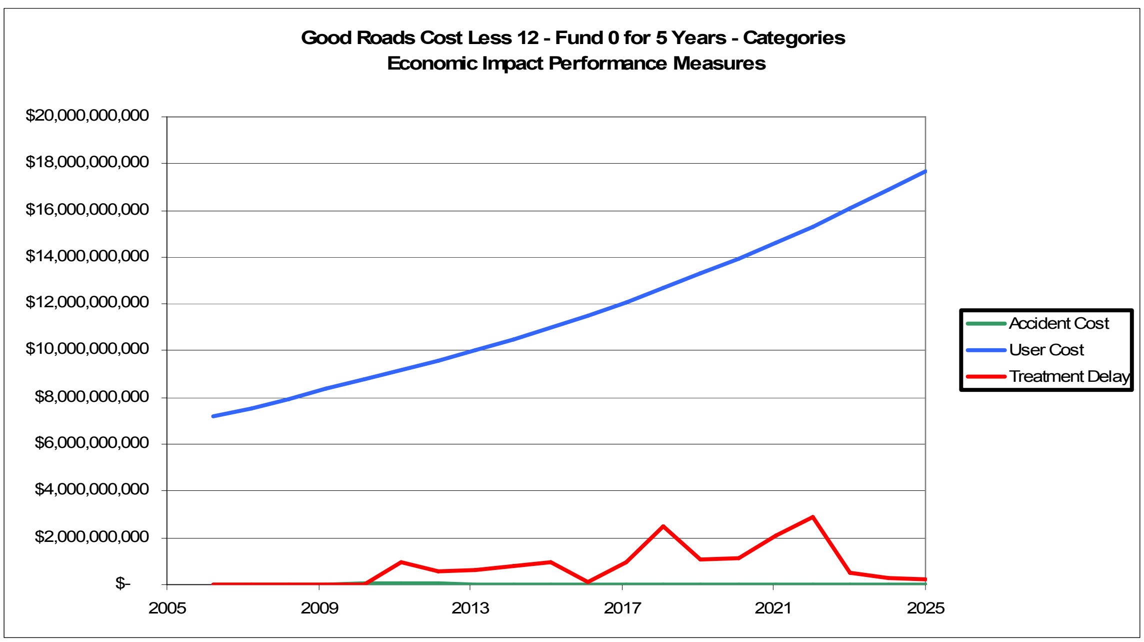


Figure 115: Strategy 12 No Funding 5 Years – WBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	0	0	0	0	0	0	0	0	0	0	**0**
2007	0	0	0	0	0	0	0	0	0	0	**0**
2008	0	0	0	0	0	0	0	0	0	0	**0**
2009	0	0	0	0	0	0	0	0	0	0	**0**
2010	0	0	0	0	0	0	0	0	0	0	**0**
2011	392.467	159.704	89.877	0	338.422	45.098	6.399	0	3.991	0	**1036**
2012	308.173	182.951	40.212	2.236	396.243	69.311	16.648	0	0	0	**1016**
2013	236.753	206.242	34.094	0.747	406.739	19.564	15.471	0	0	0	**920**
2014	78.294	274.736	23.87	4.969	351.201	48.766	21.593	0	0	0	**803**
2015	25.955	271.318	12.911	3.043	382.434	51.67	7.79	0	0	1.459	**757**
2016	0	330.815	56.856	6.837	329.009	12.845	9.389	0	3.36	6.045	**755**
2017	0	322.43	14.524	1.448	64.894	27.216	5.35	0	0	38.22	**474**
2018	0	313.751	5.746	35.003	281.332	20.351	0	0	0	1.986	**658**
2019	237.29	164.955	0	9.952	303.645	0.099	11.044	0	0	12.554	**740**
2020	366.816	16.639	0	23.547	306.635	5.305	14.281	0	12.693	0	**746**
2021	149.358	4.186	0	2.384	476.46	0	15.302	0	0	0	**648**
2022	65.759	0	0	19.074	422.025	0	13.466	0	0	1.856	**522**
2023	43.767	0	0	12.706	383.738	0	22.367	0	0	7.028	**470**
2024	26.334	0	0	44.908	382.904	3.406	8.496	0	0	0	**466**
2025	47	0	0	20.161	473.059	0	10.844	0	0	0	**551**
Total	**1978**	**2248**	**278**	**187**	**5299**	**304**	**178**	**0**	**20**	**69**	**10561**

Table 77: Strategy 12 No Funding 5 Years – WBC Treatment Distribution (miles)

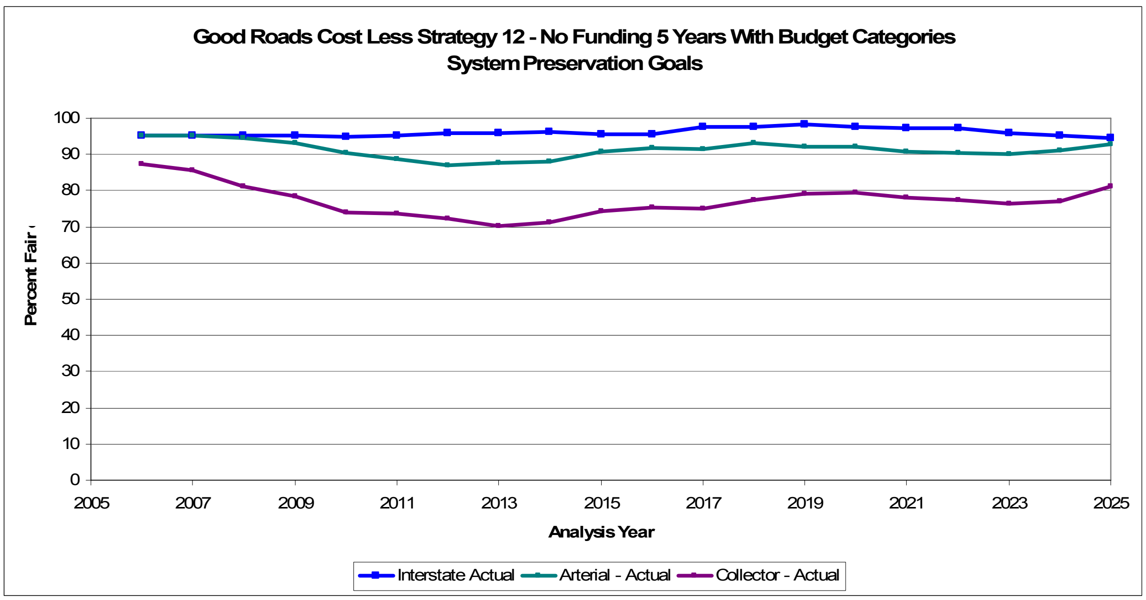


Figure 116: Strategy 12 No Funding 5 Years – WBC System Preservation Goals

5.3.21.2 Discussion

The No Funding strategy for 5 years was included in the analysis to demonstrate the affects on the UDOT highway network if the maintenance and preservation funding was eliminated to help build new and enhance existing capacity throughout the network.

As could be expected with this scenario, accident and user costs increase quite dramatically as the condition of the network deteriorates during the initial analysis period with no funding.

Following that initial period of deterioration though, this strategy with restricted Orange Book and Blue Book budgets, the network never returns to the original condition levels.

5.3.22 Strategy 13 – 50% Funding 5 Years -No Budget Categories

5.3.22.1 Results

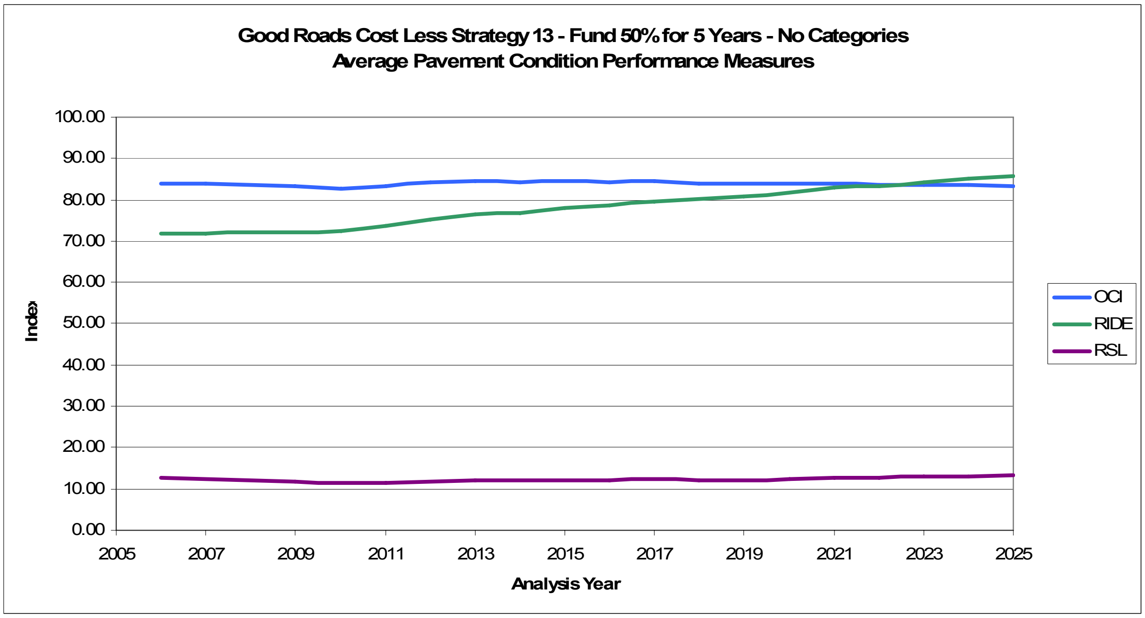


Figure 117: Strategy 13 50% Funding 5 Years – NBC Condition Performance Measures

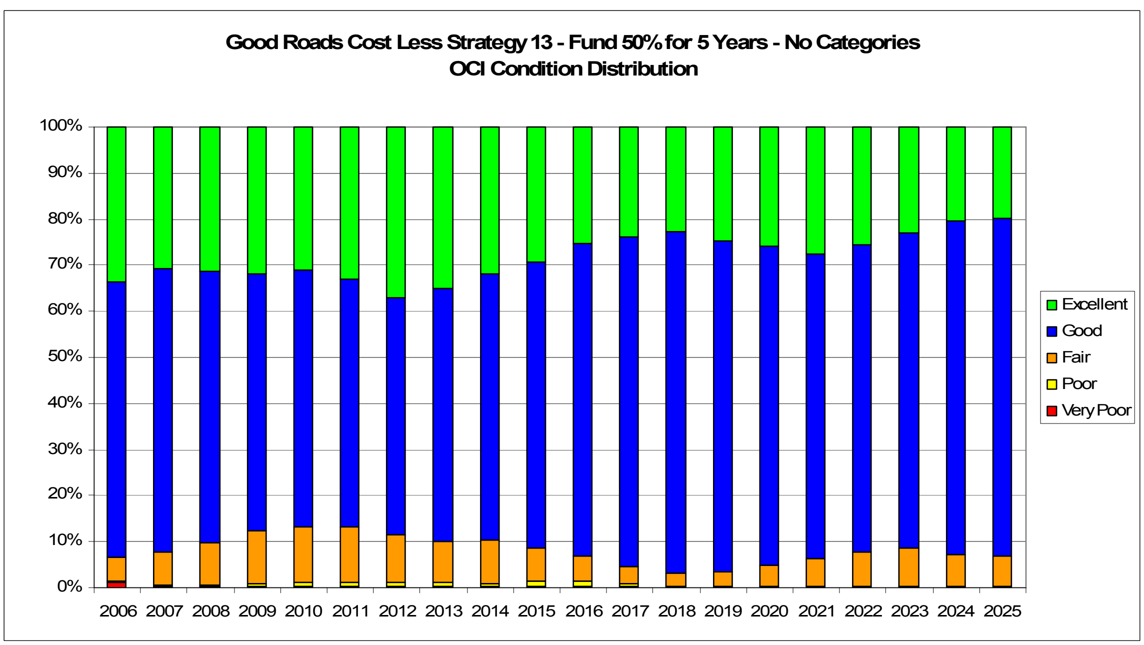


Figure 118: Strategy 13 50% Funding 5 Years – NBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$13,856,210	$7,149,522,271	$69,255,297	$60,070,432	$29,912,664	$89,983,095
2007	$11,804,905	$7,504,201,145	$24,151,506	$52,284,414	$40,388,657	$92,673,071
2008	$12,378,705	$7,869,371,304	$312,248,967	$60,935,327	$34,519,224	$95,454,551
2009	$13,743,364	$8,253,487,142	$151,410,181	$50,036,626	$48,257,561	$98,294,187
2010	$14,763,118	$8,657,578,067	$192,196,122	$62,222,859	$39,067,633	$101,290,492
2011	$15,452,992	$9,073,837,274	$223,942,136	$131,407,971	$77,243,898	$208,651,869
2012	$12,927,102	$9,498,302,966	$353,982,758	$128,541,517	$86,383,356	$214,924,873
2013	$6,855,603	$9,944,265,833	$566,845,773	$167,148,619	$54,216,694	$221,365,313
2014	$5,002,059	$10,409,520,844	$700,445,154	$188,865,613	$39,136,521	$228,002,134
2015	$2,955,143	$10,907,228,253	$851,095,547	$164,310,546	$70,507,532	$234,818,078
2016	$3,106,517	$11,453,585,865	$226,758,589	$198,614,640	$43,190,846	$241,805,486
2017	$2,743,970	$12,010,721,197	$1,131,646,255	$198,150,366	$50,952,675	$249,103,041
2018	$4,973,945	$12,581,696,307	$3,224,078,632	$248,151,671	$8,435,641	$256,587,313
2019	$5,016,818	$13,208,183,311	$369,484,528	$238,541,188	$25,721,205	$264,262,393
2020	$4,328,393	$13,863,564,567	$1,023,740,313	$246,730,882	$25,495,481	$272,226,363
2021	$2,215,549	$14,517,714,268	$1,408,522,767	$259,210,236	$21,206,076	$280,416,311
2022	$1,111,083	$15,213,030,535	$2,269,278,019	$282,090,734	$6,720,241	$288,810,975
2023	$1,229,424	$15,929,822,472	$2,673,106,778	$282,029,057	$15,433,027	$297,462,083
2024	$310,664	$16,716,989,308	$1,654,681,048	$297,323,137	$9,030,656	$306,353,793
2025	$340,938	$17,513,266,881	$1,512,996,559	$307,219,548	$8,400,271	$315,619,819
Total	$135,116,501	$232,275,889,811	$18,939,866,931	$3,623,885,383	$734,219,858	$4,358,105,241

Table 78: Strategy 13 50% Funding 5 Years – NBC Economic Impact Performance Measures

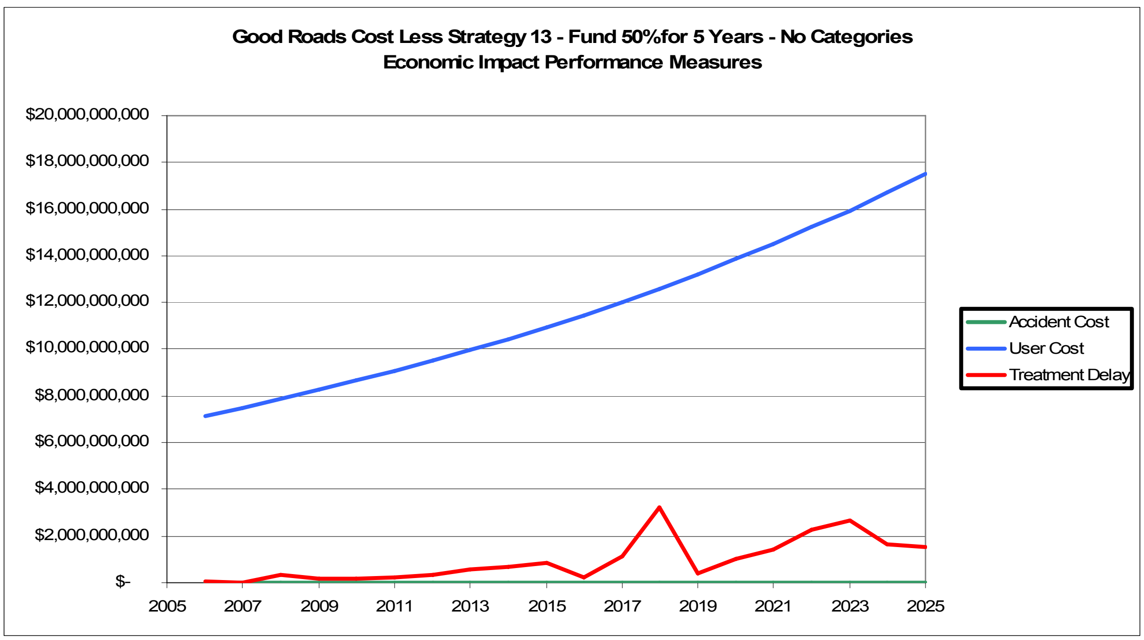


Figure 119: Strategy 13 50% Funding 5 Years – NBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	100	94	25	0	90	60	0	8	7	1	**385**
2007	150	122	17	0	94	29	6	9	0	6	**434**
2008	61	132	5	0	194	41	10	14	0	0	**457**
2009	140	163	25	1	138	15	3	0	0	0	**485**
2010	200	105	1	1	184	27	2	0	0	0	**520**
2011	115	263	2	2	415	17	21	0	0	1	**836**
2012	336	222	51	0	377	24	33	0	0	0	**1043**
2013	135	186	16	12	450	15	15	0	0	0	**829**
2014	214	83	43	5	138	13	10	0	0	38	**545**
2015	258	142	20	34	346	33	23	0	0	2	**860**
2016	186	109	0	19	237	0	23	0	18	13	**604**
2017	252	93	0	34	375	19	16	0	17	0	**805**
2018	98	7	0	46	255	20	2	0	24	7	**458**
2019	196	0	0	41	442	4	32	0	13	0	**727**
2020	307	0	0	9	508	2	9	0	0	13	**846**
2021	155	0	0	3	634	68	22	0	0	0	**882**
2022	24	0	0	29	439	48	11	0	0	14	**564**
2023	52	0	0	10	629	55	19	7	0	0	**772**
2024	90	0	0	37	621	14	13	0	0	0	**775**
2025	47	0	0	25	681	26	8	0	0	0	**787**
Total	**3117**	**1721**	**205**	**308**	**7246**	**529**	**278**	**38**	**79**	**94**	**13615**

Table 79: Strategy 13 50% Funding 5 Years – NBC Treatment Distribution (miles)

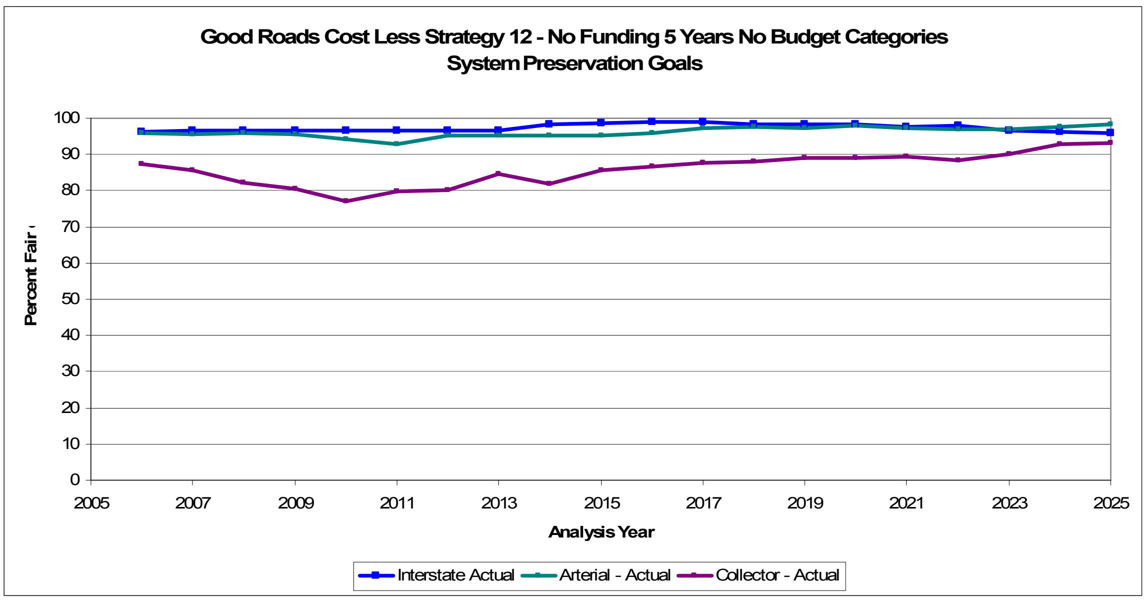


Figure 120: Strategy 13 50% Funding 5 Years – NBC System Preservation Goals

5.3.22.2 Discussion

The 50% Funding for Five year scenario enables UDOT to remove approximately $500 million dollars from the maintenance and rehabilitation funding to devote to building new capacity and enhancing existing capacity throughout the network.

Within this strategy where there are no fixed budget categories and dTIMS CT can determine the amount of Orange Book and Blue Book projects, the network is only slightly impacted by the reduced funding. There is an increase in accident costs and user costs during the initial period of the analysis but when full funding resumes at the end to the five year period, the network starts to return to normal accident costs and user costs.

In terms of average condition, the initial period of reduced funding sees a drop in average condition of 5% and the system never achieves the original condition level and in fact finishes with an average condition of 77.69 which is again approximately 5% lower than the initial starting value. Clearly this scenario results in lower conditions during the analysis period and the conditions never recover to current levels.

5.3.23 Strategy 13 – 50% Funding 5 Years -With Budget Categories

5.3.23.1 Results

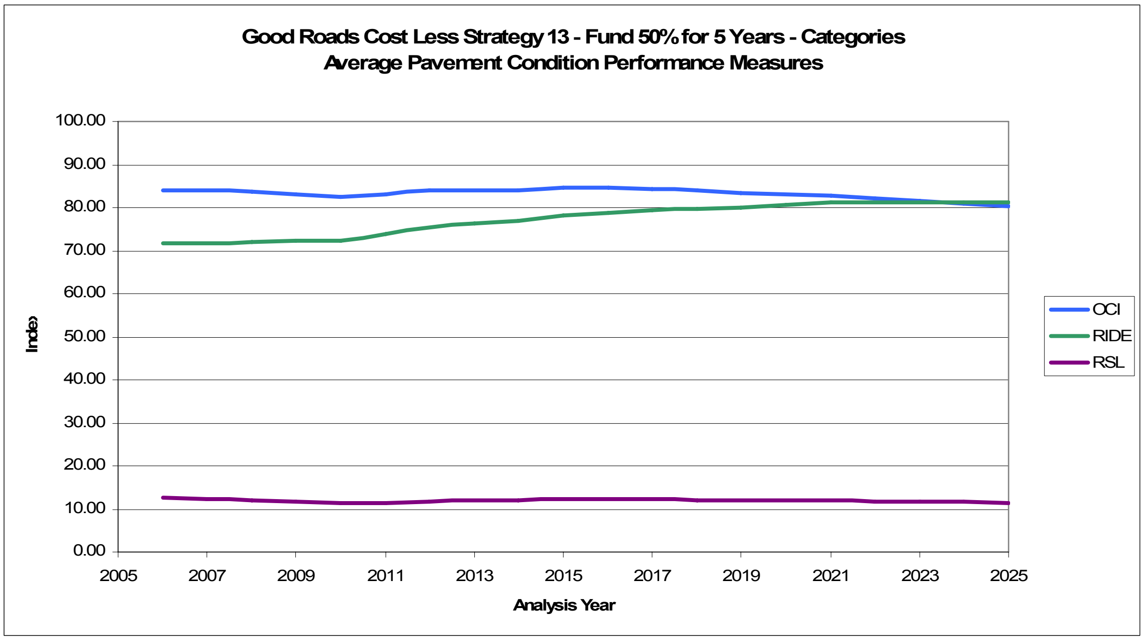


Figure 121: Strategy 13 50% Funding 5 Years – WBC Condition Performance Measures

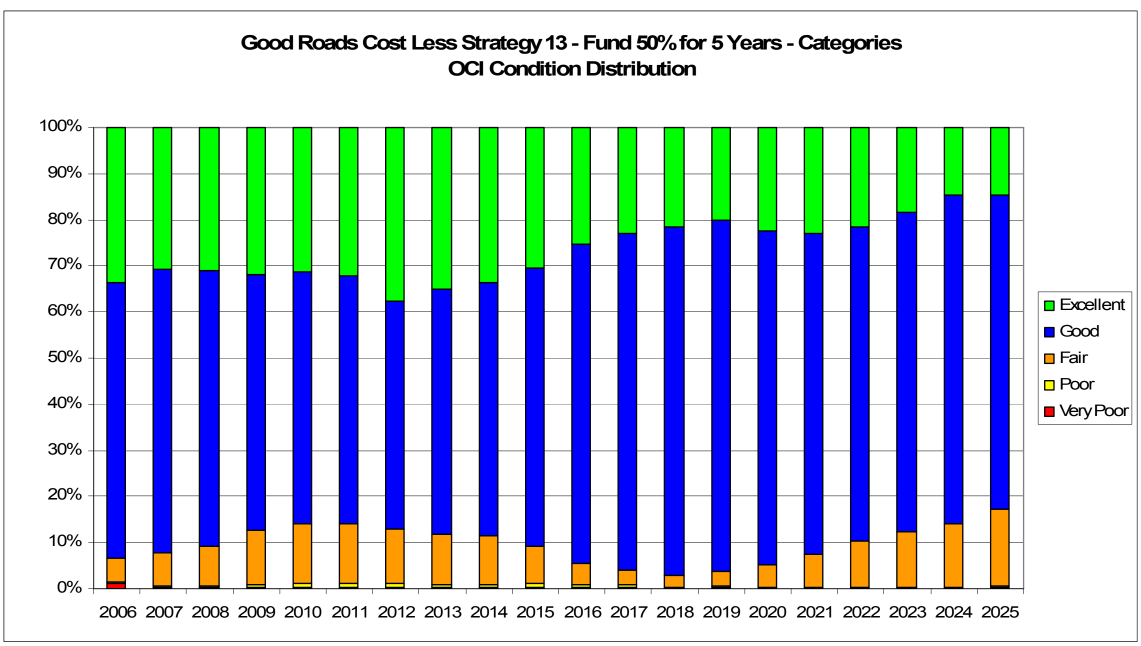


Figure 122: Strategy 13 50% Funding 5 Years – WBC OCI Condition Distribution

Analysis Year	Accident Cost	User Cost	Treatment Delay Cost	Blue Book Program	Orange Book Program	Total Program Cost
2006	$13,791,359	$7,149,733,250	$69,671,490	$59,986,233	$29,983,337	$89,969,570
2007	$11,725,199	$7,504,644,143	$35,786,380	$61,797,679	$30,868,067	$92,665,746
2008	$12,511,073	$7,868,611,877	$312,571,041	$63,642,412	$31,785,677	$95,428,089
2009	$13,888,224	$8,250,613,223	$167,493,100	$65,512,825	$32,740,151	$98,252,976
2010	$14,282,493	$8,650,881,322	$206,795,429	$67,447,791	$33,714,053	$101,161,845
2011	$15,638,789	$9,069,470,978	$163,372,680	$139,019,453	$69,506,626	$208,526,079
2012	$13,858,832	$9,493,009,020	$387,829,248	$143,283,279	$71,599,488	$214,882,767
2013	$5,137,608	$9,941,778,108	$574,596,806	$147,577,378	$73,670,582	$221,247,960
2014	$3,347,692	$10,404,876,342	$679,475,207	$151,988,992	$75,933,178	$227,922,169
2015	$3,723,939	$10,909,700,496	$829,601,242	$156,535,590	$78,077,319	$234,612,910
2016	$2,641,736	$11,448,094,666	$231,971,944	$161,125,784	$80,438,700	$241,564,484
2017	$2,810,095	$12,010,506,037	$1,076,454,551	$166,004,186	$57,869,126	$223,873,311
2018	$2,718,271	$12,593,875,582	$2,454,503,028	$170,931,868	$23,353,273	$194,285,141
2019	$3,036,927	$13,214,087,577	$1,215,640,271	$176,130,642	$29,505,644	$205,636,285
2020	$1,585,425	$13,867,088,698	$1,087,144,439	$181,474,435	$40,895,695	$222,370,130
2021	$1,940,955	$14,527,064,693	$1,332,922,631	$186,944,059	$22,169,502	$209,113,561
2022	$817,448	$15,230,028,189	$2,278,793,409	$192,406,855	$13,085,811	$205,492,666
2023	$916,214	$15,958,413,958	$2,648,712,978	$198,286,691	$13,575,038	$211,861,729
2024	$222,743	$16,749,843,896	$1,795,307,716	$204,291,843	$5,867,251	$210,159,094
2025	$260,523	$17,556,224,350	$1,279,036,610	$210,344,835	$11,739,178	$222,084,012
Total	**$124,855,544**	**$232,398,546,403**	**$18,827,680,200**	**$2,904,732,831**	**$826,377,695**	**$3,731,110,525**

Table 80: Strategy 13 50% Funding 5 Years – WBC Economic Impact Performance Measures

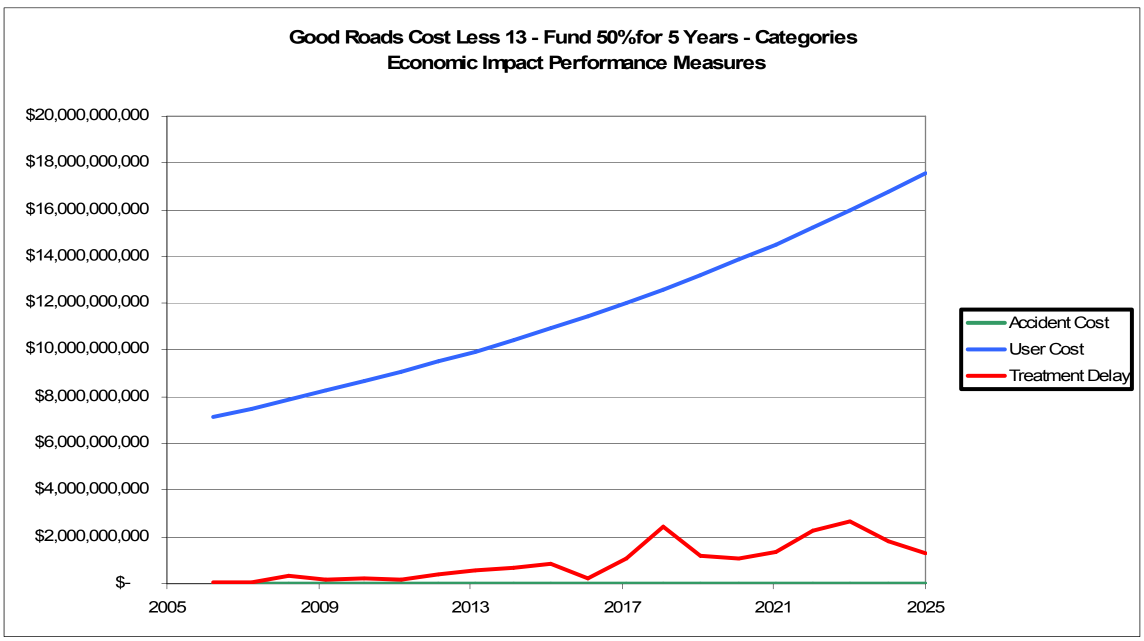


Figure 123: Strategy 13 50% Funding 5 Years – WBC Economic Impact Performance Measures

TREATMENT LENGTH SUMMARY											
Year	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
2006	93	101	25	0	85	60	4	0	7	1	**376**
2007	108	70	17	0	166	29	6	9	0	3	**409**
2008	61	124	5	0	197	49	10	7	0	0	**454**
2009	150	99	25	1	163	23	3	1	0	1	**466**
2010	196	72	1	1	190	27	4	0	0	0	**491**
2011	151	236	33	3	438	7	24	0	0	0	**891**
2012	341	157	26	4	408	35	33	0	0	0	**1005**
2013	120	238	11	6	285	15	17	0	0	15	**709**
2014	203	189	38	0	161	19	33	0	0	26	**669**
2015	242	247	15	37	364	33	12	0	0	0	**949**
2016	217	230	24	2	242	0	23	0	2	15	**755**
2017	273	105	0	25	218	19	16	0	20	0	**676**
2018	170	17	0	50	256	20	8	0	7	0	**528**
2019	318	0	0	8	311	0	27	0	10	7	**680**
2020	429	14	0	19	354	5	16	0	8	0	**846**
2021	164	0	0	0	453	60	21	0	0	0	**698**
2022	36	0	0	10	391	48	18	1	0	2	**506**
2023	116	0	0	0	429	56	12	3	0	0	**616**
2024	28	0	0	17	409	23	13	0	0	0	**489**
2025	43	0	0	0	503	26	11	1	0	0	**583**
Total	**3459**	**1898**	**220**	**184**	**6024**	**553**	**311**	**22**	**55**	**69**	**12796**

Table 81: Strategy 13 50% Funding 5 Years – WBC Treatment Distribution (miles)

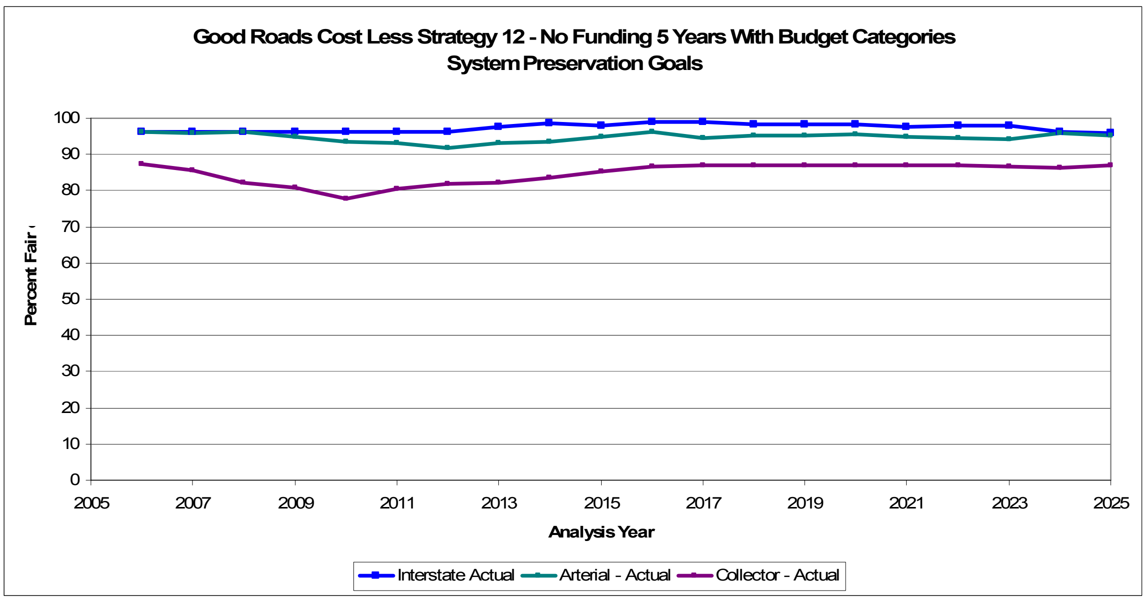


Figure 124: Strategy 13 50% Funding 5 Years – WBC System Preservation Goals

5.3.23.2 Discussion

The 50% Funding for Five year scenario enables UDOT to remove approximately $500 million dollars from the maintenance and rehabilitation funding to devote to building new capacity and enhancing existing capacity throughout the network.

As has been seen with other strategies within the study, the restrictions placed on the analysis with Orange Book and Blue Book budget categories cause this analysis not to return the network to the original condition prior to the end of the analysis.

6. Good Roads Cost Less Study Conclusions

The thirteen different strategies with twenty-three different optimizations in the Good Roads Cost Less study analysis generated a sizeable amount of variables that were summarized in graphical and table format throughout Section 5. Reading through that section though, it is difficult to gain a broad understanding of the results of the study in terms of the whole study and not each individual strategy.

Before drawing any conclusions and recommendations from the study, it is first necessary to present the results in more of a global format so that the conclusions and recommendations might be more easily illustrated. Within this section a broad view of each of the study variables will be presented and discussed and then the section will be completed with the conclusions and recommendations of the study.

The summary graphs contained within this section utilize the strategy number and an indicator of whether the budget categories were used or not as follows:

Strategy	Strategy	Strategy
01	Do Nothing	01
02	Maintenance Only	02
03	Reconstruction Only	03
04	Current Model - No Categories	04N
04	Current Model - Categories	04W
05	Cycle 6 Years and 10 Years - No Categories	05N
05	Cycle 6 Years and 10 Years - Categories	05W
06	Cycle 6 Years and 12 Years - No Categories	06N
06	Cycle 6 Years and 12 Years - Categories	06W
07	Cycle 8 Years and 10 Years - No Categories	07N
07	Cycle 8 Years and 10 Years - Categories	07W
08	Cycle 8 Years and 12 Years - No Categories	08N
08	Cycle 8 Years and 12 Years - Categories	08W
09	Cycle 10 Years and 10 Years - No Categories	09N
09	Cycle 10 Years and 10 Years - Categories	09W
10	Condition 10% Less - No Categories	10N
10	Condition 10% Less - Categories	10W
11	Condition 20% Less - No Categories	11N
11	Condition 20% Less - Categories	11W
12	No Funding Five Years - No Categories	12N
12	No Funding Five Years - Categories	12W
13	50% Funding Five Years - No Categories	13N
13	50% Funding Five Years - Categories	13W

Table 82: Summary Chart Strategy Index

6.1 Economic Performance Measures

The following sections discuss the results of the analysis and highlight the economic performance measures that resulted from the strategies.

6.1.1 Agency Costs

Within each strategy, each optimization set was given the same budget amounts either as a total figure (no budget categories) or split into two different budget categories (the Orange Book minor maintenance and preservation category and the Blue Book rehabilitation and reconstruction category). The total 20 year analysis budget available was as follows:

Strategy	Total Available	Blue Book	Blue Book
No Budget Categories	$4,836,667,408	n/a	n/a
With Budget Categories	$4,836,667,408	$3,224,444,939	$1,612,222,469

Table 83: Optimization Budget Amounts

Strategy 12 and Strategy 13 had reduced funding in the initial 5 years of the analysis so the total available budget for those two analyses was slightly less.

The total expenditure of each strategy is outlined in Figure 125 as follows:

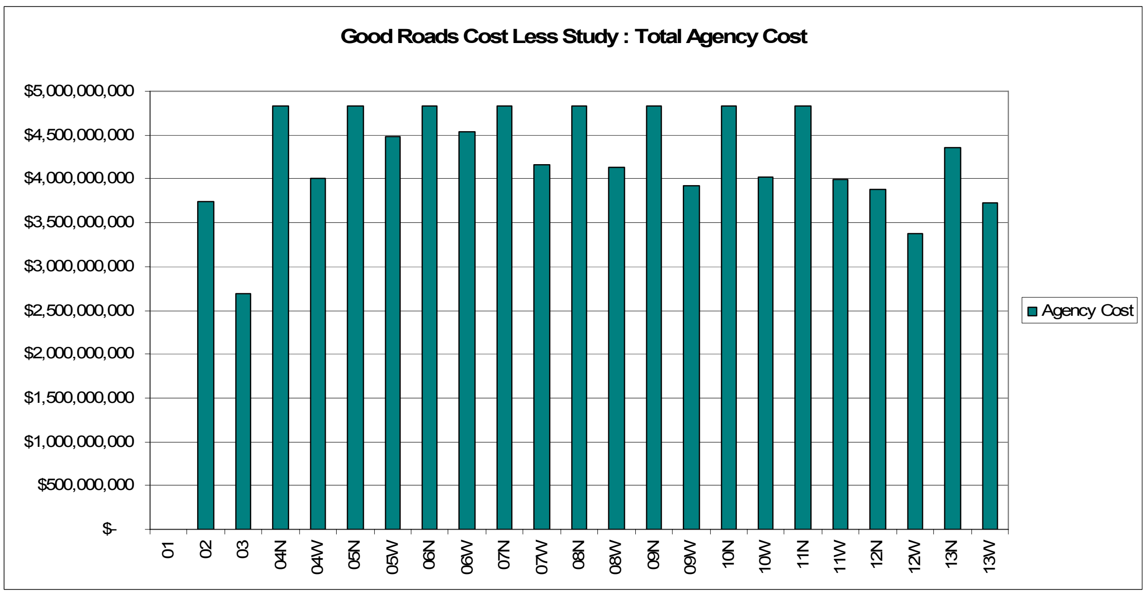


Figure 125: Total Agency Cost by Strategy

One thing that is evident immediately when looking at the Total Agency Costs is that the analysis consistently spent the entire budget amount in strategies where budget categories were not used. The strategies where the budget categories are used consistently do not spend the entire available budget and in some instances a surplus of $800 million goes unspent on the highway network. This surplus of funds is caused by timing of the maintenance and minor preservation treatments as well as the trigger mechanisms for these treatments which need to be investigated within the PMS model.

When the Agency Costs are presented in terms of Budget Categories, the source of the shortfall in expenditure becomes evident as shown in Figure 126.

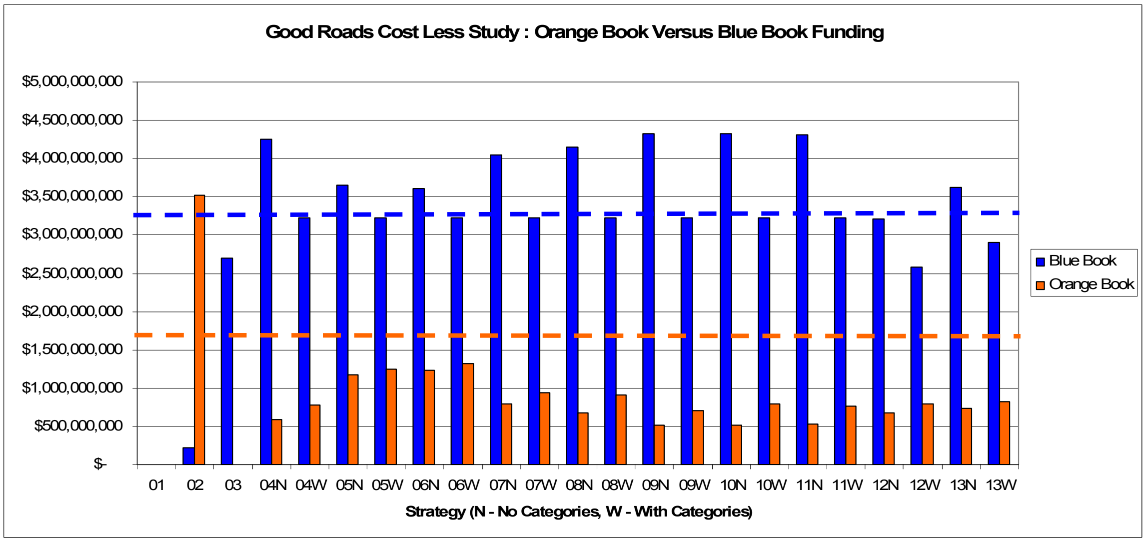


Figure 126: Orange Book versus Blue Book Funding

Orange book expenditures consistently fall below the available budget in the strategies where budget categories are used while the Blue book budget category consistently reaches full expenditure. When the maintenance cycle is shortened (Strategy 5 and Strategy 6) the Orange book expenditure is the greatest and a more thorough study of the timing cycle of Orange book treatments will be one of the recommendations of this study.

One of the explanations for the optimization selecting Blue book minor rehabilitation treatments over orange book seal treatments can be explained by looking at the costs and the benefits of each treatment. The Open Graded Seal Coat treatment costs slightly less than the Asphalt Minor Rehab treatment but the Asphalt Minor Rehab treatment gives significantly more benefit to the pavement. For the slight increase in cost, the benefits are higher so dTIMS CT prefers to select the Asphalt Minor Rehab over the Open Graded Seal Coat in many of the alternative strategies.

6.1.2 User Costs

The analysis has demonstrated that user costs within the network are increasing and will no doubt be a concern for motorists in the future. It is important to note here, that the user cost figures quoted in the report refer to the total user operating cost, not just the additional cost due to increased roughness. The User Costs range from a low of $229 billion to a high of $244 billion as shown in Figure 127.

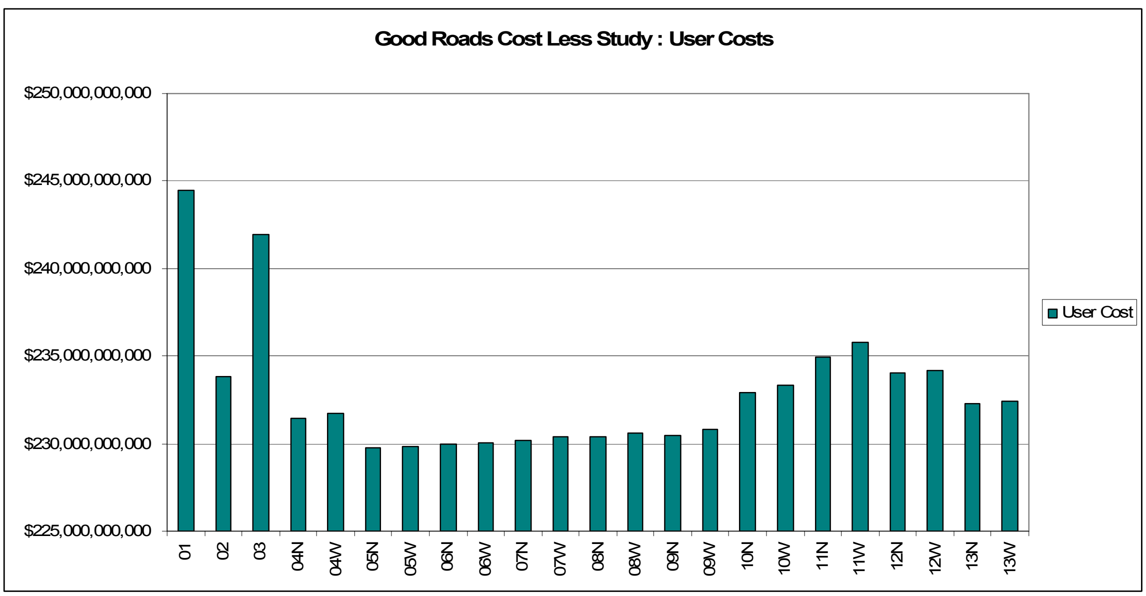


Figure 127: User Costs for By Strategy

It is important to note that the traffic level, percent trucks and user costs calculations are consistent within each of the strategies. The only variable that changed from strategy to strategy was the Ride Index which plays a role in the calculation of user costs.

What can be seen from the analysis results from Strategies 4 through 9 is that the user costs are relatively consistent around the $230 billion dollar level. This would be related to the fact that the traffic is consistent through all of the strategies and each strategy keeps the Ride Index approximately the same throughout the analysis. The only large scale change in users costs come when the condition of the network deteriorates greatly as with the initial strategies (Strategies 1,2,3, 10 and 11) and when the funding is reduced (Strategies 12 and 13).

This evidence is further supported by the next figure which presents the user costs along with the Ride index variable in year 20 of the analysis.

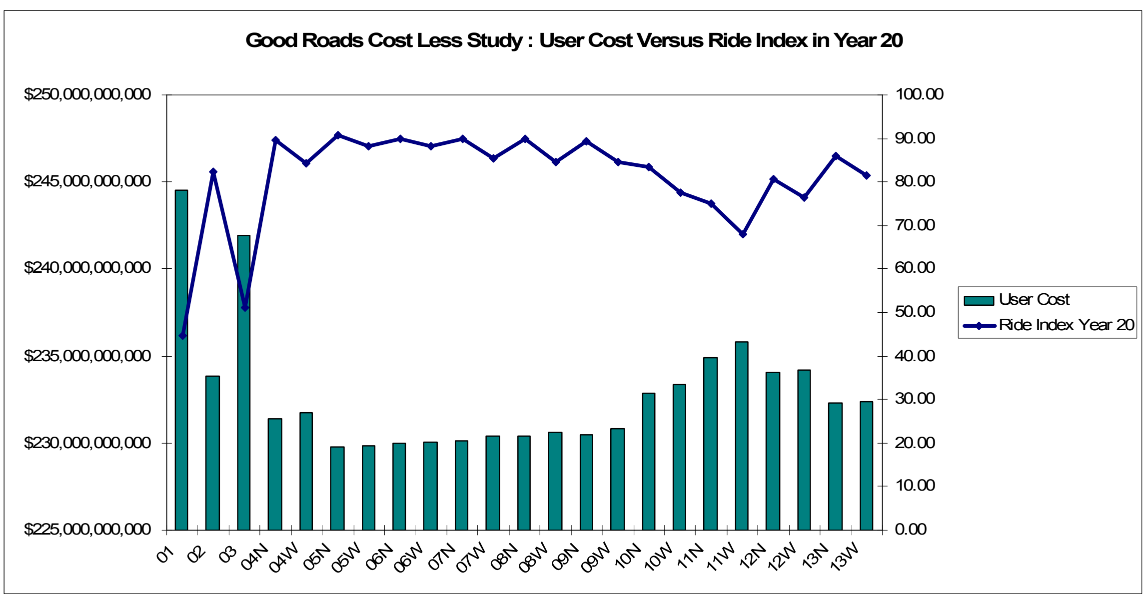


Figure 128: User Cost versus Ride Index

Clearly as far as user costs are concerned, a smooth ride helps reduce the total vehicle operating costs over the life of the analysis. But, a significant change in the Ride Index does not necessarily increase or decrease the user costs significantly. When the Ride index is reduced by 10% the User Costs increase by less than 1% and when the Ride Index is reduced by 20%, the User Costs increase by only 1.5%. The overall user costs for the UDOT highway network are increasing dramatically for each scenario because the traffic levels across the highway network are increasing yearly. Within the analysis, an average annual growth rate of 5% was applied to the traffic volume for each pavement section, which causes the vehicle operating costs to increase significantly within each of the analyses completed for the study.

6.1.3 Accident Costs

Much like User Costs and the Ride Index, Accident Costs within the analysis vary primarily based on the values of the Skid Number as the other variables are constant throughout each strategy.

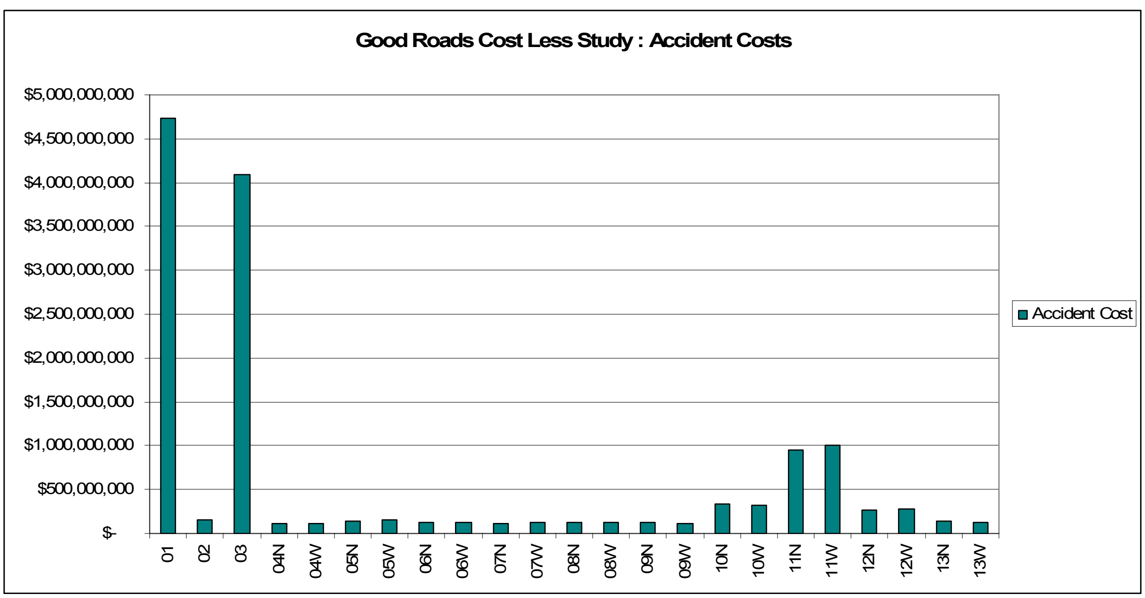


Figure 129: Accident Costs by Strategy

The increased Accident Costs based entirely on the Skid Number do not really play a factor in the analysis for strategies 4 through 9 (maximum of $159 million), but when funding is significantly reduced or the conditions of the network allowed to deteriorate into a fair and even a poor condition, the accident costs based on the deteriorating skid numbers increase quite quickly. The UDOT highway network is in good condition and in the case of accident costs, good roads do cost less.

These Accident costs are different and much lower than agency costs and user costs for the following reasons:

- Accident Costs are a "delta cost" between increased accident rates due to low skid numbers and not the total cost of all accidents occurring on UDOT Highways;

- Not all safety related costs are included within the accident cost figures: costs due to roughness, rutting, potholes, edge drop offs and other factors are not included within the cost figures;

- Costs to society and to UDOT due to lawsuits between persons involved in the accident (and UDOT on occasion) take funds away from other important department activities and are not taken into consideration.

6.1.4 Delay Costs

Delay costs give an indication as to which strategies impact the public the most through the delay caused by implementing the recommended maintenance and rehabilitation projects.

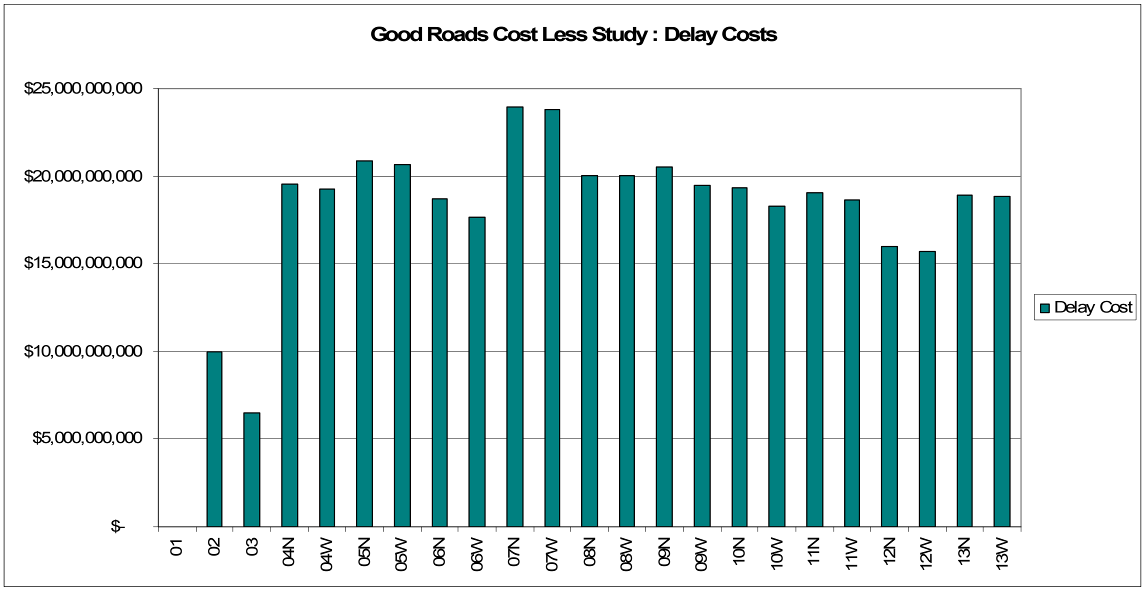


Figure 130: Delay Costs by Strategy

As can be seen in the results, the mix of minor maintenance and rehabilitation treatments has a slight impact on the Delay Costs as the minor treatments can be done without causing a great deal of delay. The strategies where the Blue book program expenditure far outweighs the Orange book program expenditure, the delay costs are slightly higher.

As you may remember from the individual strategy results, Strategy 7 sets the timing cycle to 8 years and 10 years and within this strategy approximately half of all the treatments completed within the analysis period are Minor Rehabilitation treatments which leads to an increase in delay costs which are higher than any other strategy. The miles of each treatment for each strategy are displayed in Table 84 as follows:

Strategy	Chip Seal	Functional Repair	Grind	Major Rehab Asp	Minor Rehab Asp	Minor Rehab Con	OG Seal	Prev Mtce Con	Recon Asp	Recon Conc	Total
01	0	0	0	0	0	0	0	0	0	0	0
02	1861	11990	677	0	0	0	311	193	0	0	15032
03	0	0	0	0	0	0	0	0	506	264	770
04N	3558	771	147	455	8276	638	358	79	119	121	14523
04W	3886	1474	193	235	6706	622	363	89	79	74	13721
05N	7636	1024	130	552	6002	723	733	532	143	115	17591
05W	7984	1149	130	380	5608	703	701	600	120	103	17479
06N	7583	949	89	833	5053	701	794	590	161	115	16867
06W	7879	1242	101	690	4690	679	731	657	134	103	16907
07N	3740	1132	138	467	7535	780	437	375	127	103	14834
07W	4370	1557	136	173	6432	808	429	375	96	93	14469
08N	3272	910	89	600	7248	790	426	223	156	115	13829
08W	3987	1588	101	220	5969	738	448	324	121	103	13599
09N	2026	1043	137	497	8053	851	274	56	141	103	13181
09W	2809	1559	159	135	6682	865	317	62	94	81	12762
10N	1617	1355	253	617	8658	558	177	48	52	90	13425
10W	1658	2523	273	382	6511	558	178	34	27	70	12213
11N	435	1928	329	1105	7169	361	93	31	33	108	11593
11W	393	3080	343	620	5669	361	97	6	17	82	10668
12N	1820	1871	280	343	6385	302	180	0	39	69	11289
12W	1978	2248	278	187	5299	304	178	0	20	69	10561
13N	3117	1721	205	308	7246	529	278	38	79	94	13615
13W	3459	1898	220	184	6024	553	311	22	55	69	12796

Table 84: Strategy Treatment Lengths (miles)

6.2 Condition Performance Measures

The following sections discuss the results of the analysis and highlight the economic performance measures that resulted from the strategies.

6.2.1 The Overall Condition Index (OCI)

Figure 131 displays the resulting OCI in the last year of the analysis along with the total Agency Costs for each strategy.

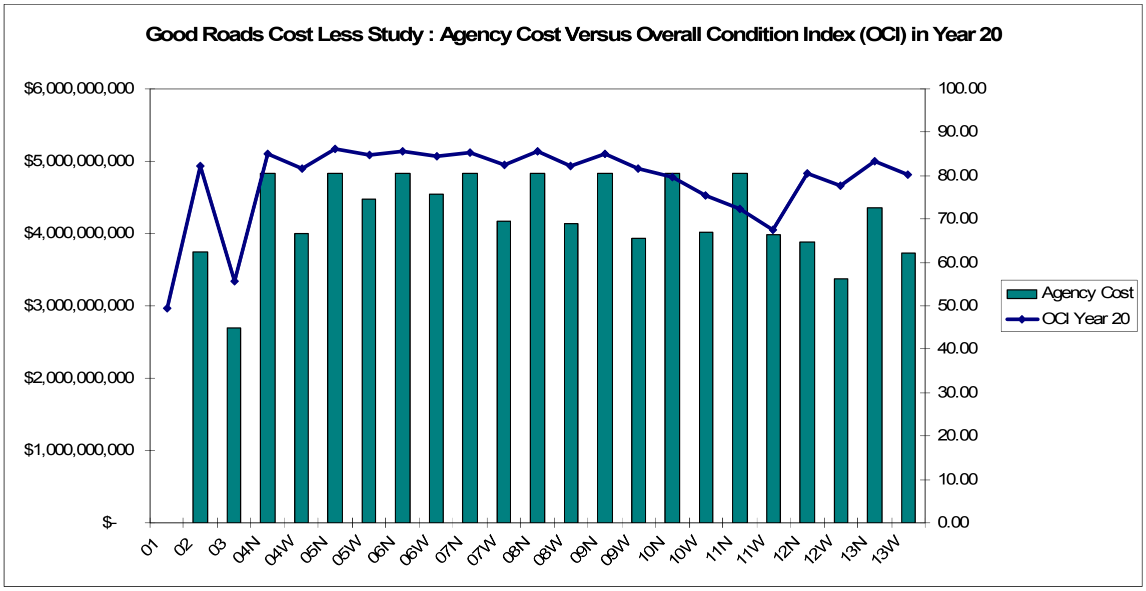


Figure 131: Agency Costs versus Overall Condition Index (OCI)

In order to display the yearly average OCI values for comparison, the strategies were split into two categories, No Budget Categories (Figure 132) and With Budget Categories (Figure 133).

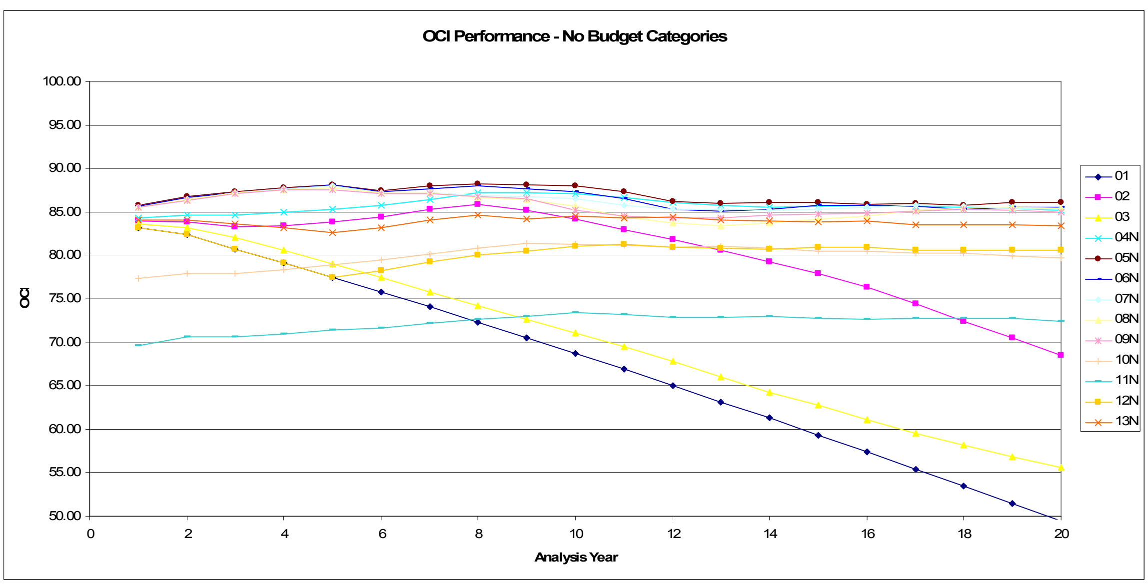


Figure 132: OCI Performance – No Budget Categories

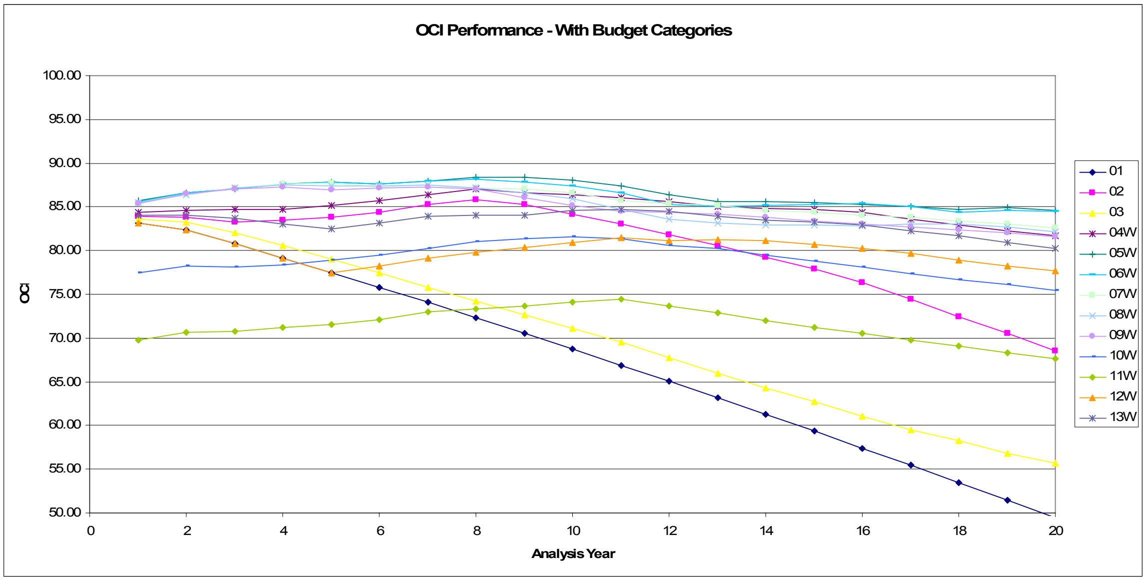


Figure 133: OCI Performance – With Budget Categories

When adequate funding is applied to the network and appropriate mix of maintenance and rehabilitation strategies are used, the OCI can be maintained at its current levels. When less than adequate funding is applied to the network or when inappropriate strategies such as "worst first" (Strategy 3) are used, the OCI deteriorates consistently throughout the analysis.

6.2.2 The Ride Index

Figure 134 displays the resulting Ride Index in the last year of the analysis along with the total Agency Costs for each strategy.

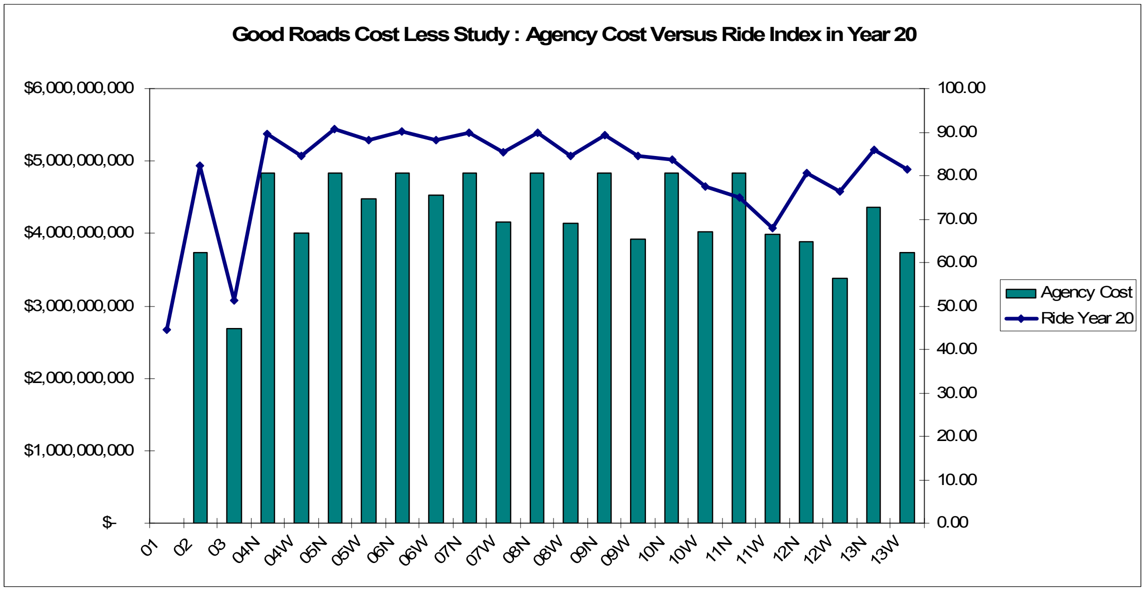


Figure 134: Agency Costs versus Ride Index

In order to display the yearly average Ride values for comparison, the strategies were split into two categories, No Budget Categories (Figure 135) and With Budget Categories (Figure 136).

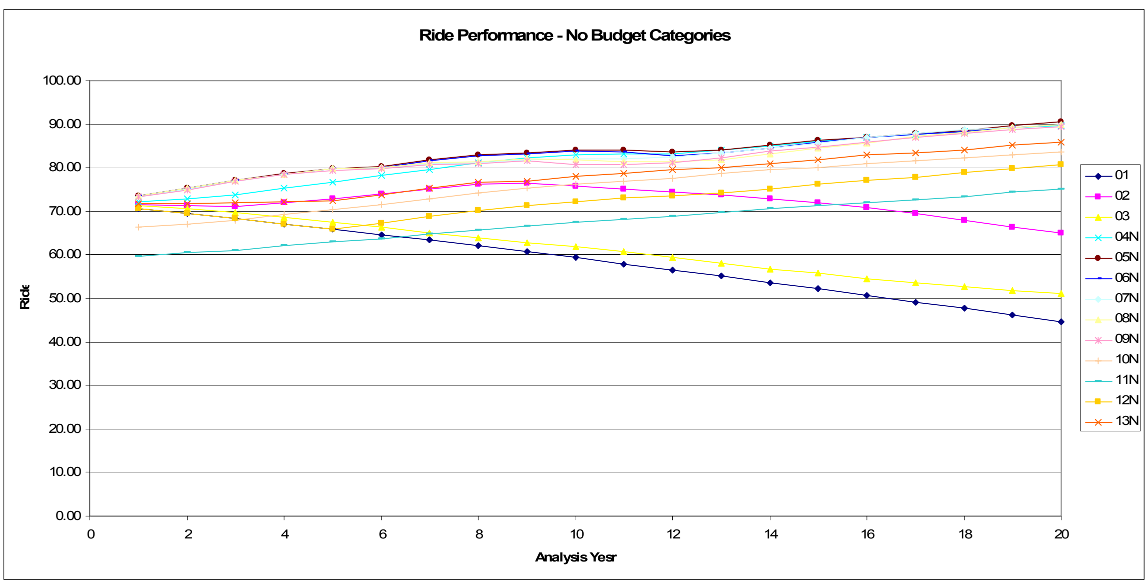


Figure 135: Ride Performance – No Budget Categories

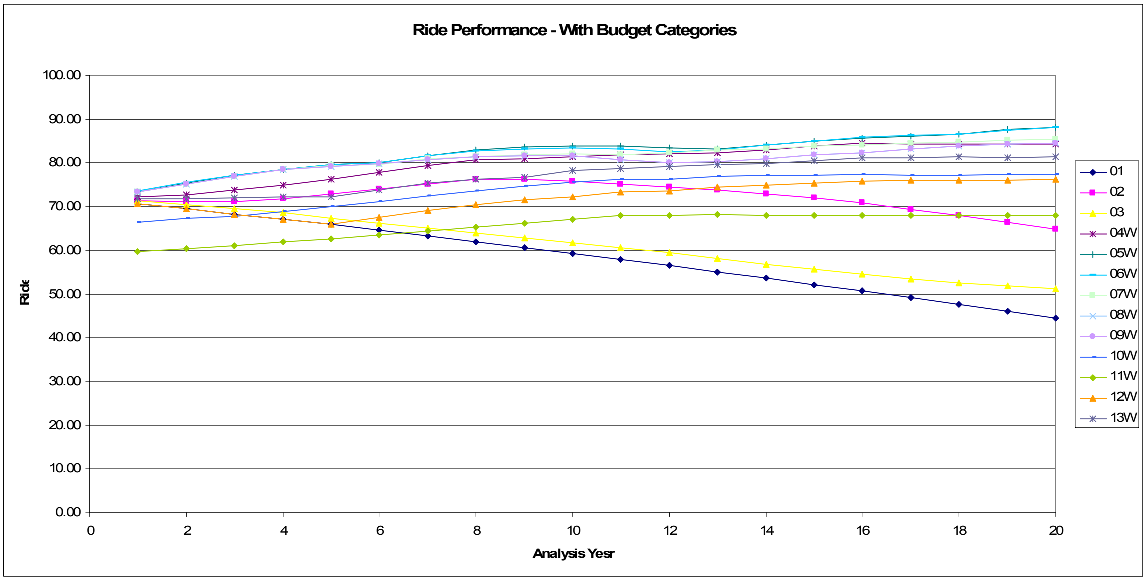


Figure 136: Ride Performance – With Budget Categories

When adequate funding is applied to the network and appropriate mix of maintenance and rehabilitation strategies are used, the Ride Index can be actually improved throughout the analysis period. When less than adequate funding is applied to the network or when inappropriate strategies such as "worst first" (Strategy 3) are used, the Ride Index deteriorates throughout the analysis.

6.2.3 The RSL Index

Figure 137 displays the resulting Remaining Service Life Index (RSL) in the last year of the analysis along with the total Agency Costs for each strategy.

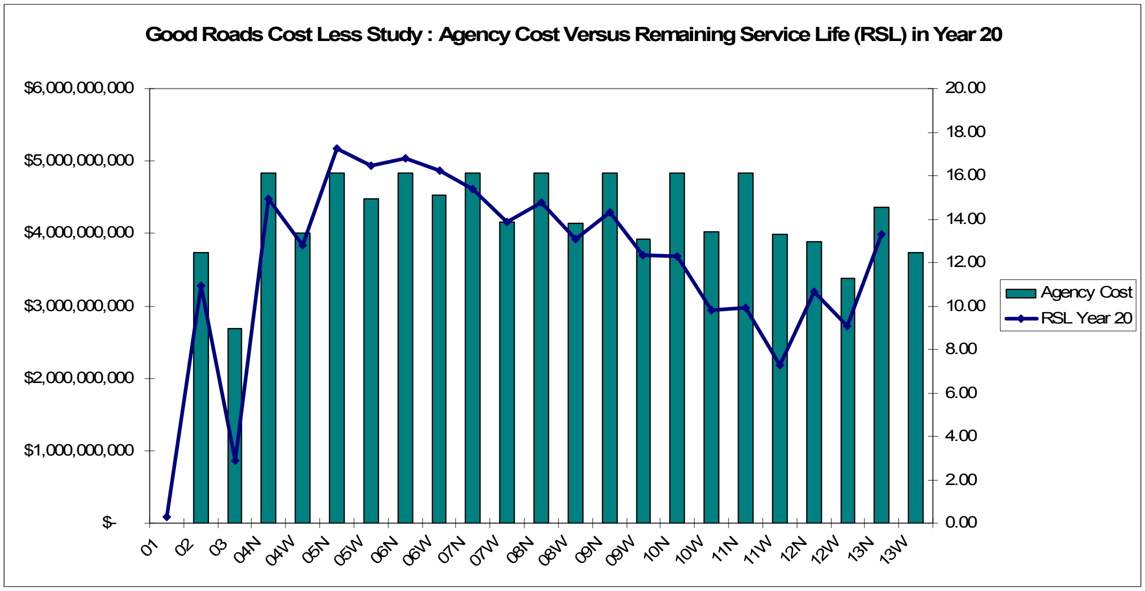


Figure 137: Agency Costs versus Remaining Service Life (RSL)

In order to display the yearly average RSL values for comparison, the strategies were split into two categories, No Budget Categories (Figure 138) and With Budget Categories (Figure 139).

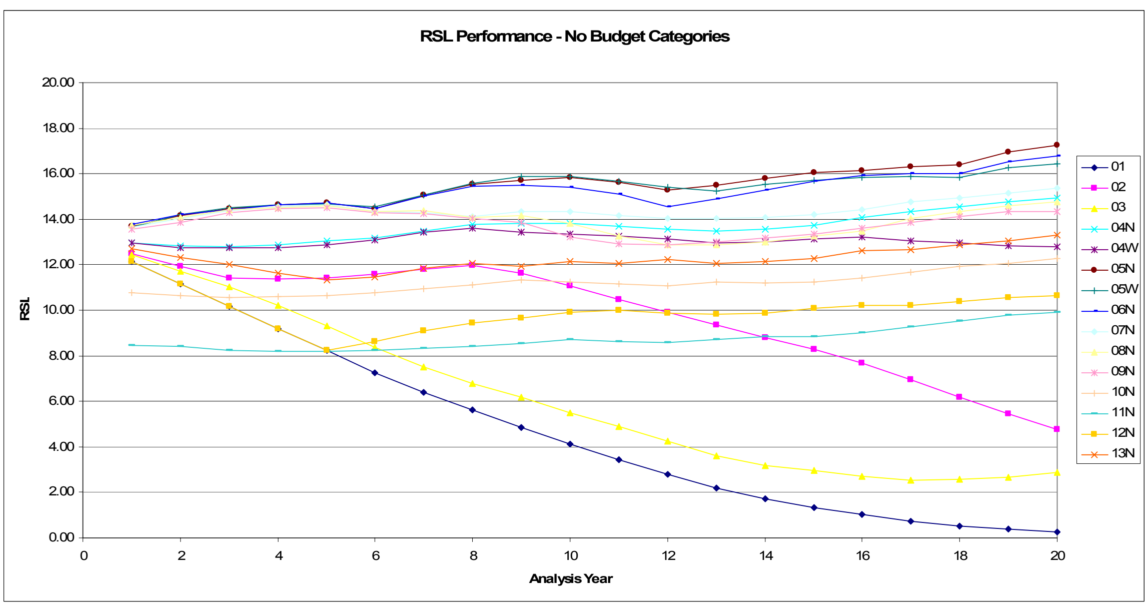


Figure 138: RSL Performance – No Budget Categories

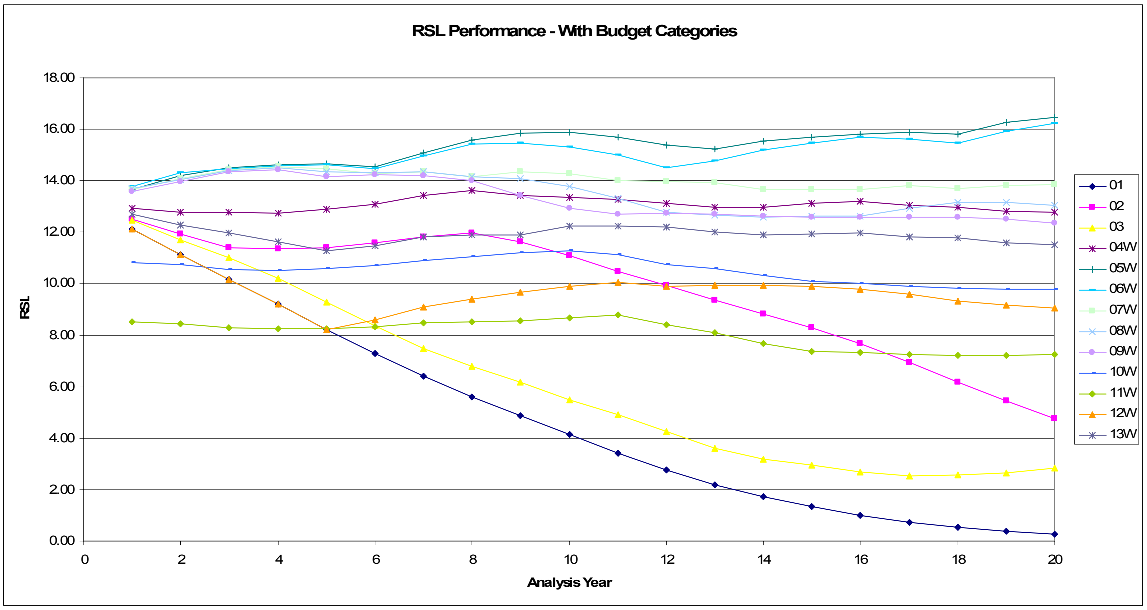


Figure 139: RSL Performance – With Budget Categories

When adequate funding is applied to the network and appropriate mix of maintenance and rehabilitation strategies are used, the RSL Index can be actually improved throughout the analysis period. When less than adequate funding is applied to the network or when inappropriate strategies such as "worst first" (Strategy 3) are used, the RSL deteriorates throughout the analysis.

6.2.4 Looking Forward – 2025 to 2045

Once the analysis was completed and the initial summary graphs completed for each strategy, a table was produced that looked at the program requirements for each strategy for the next 20 years in order to determine what type of funding would be required based on the conditions of the network in 2025. Figure 140 presents the condition distributions for each strategy following the final year of the analysis (2025).

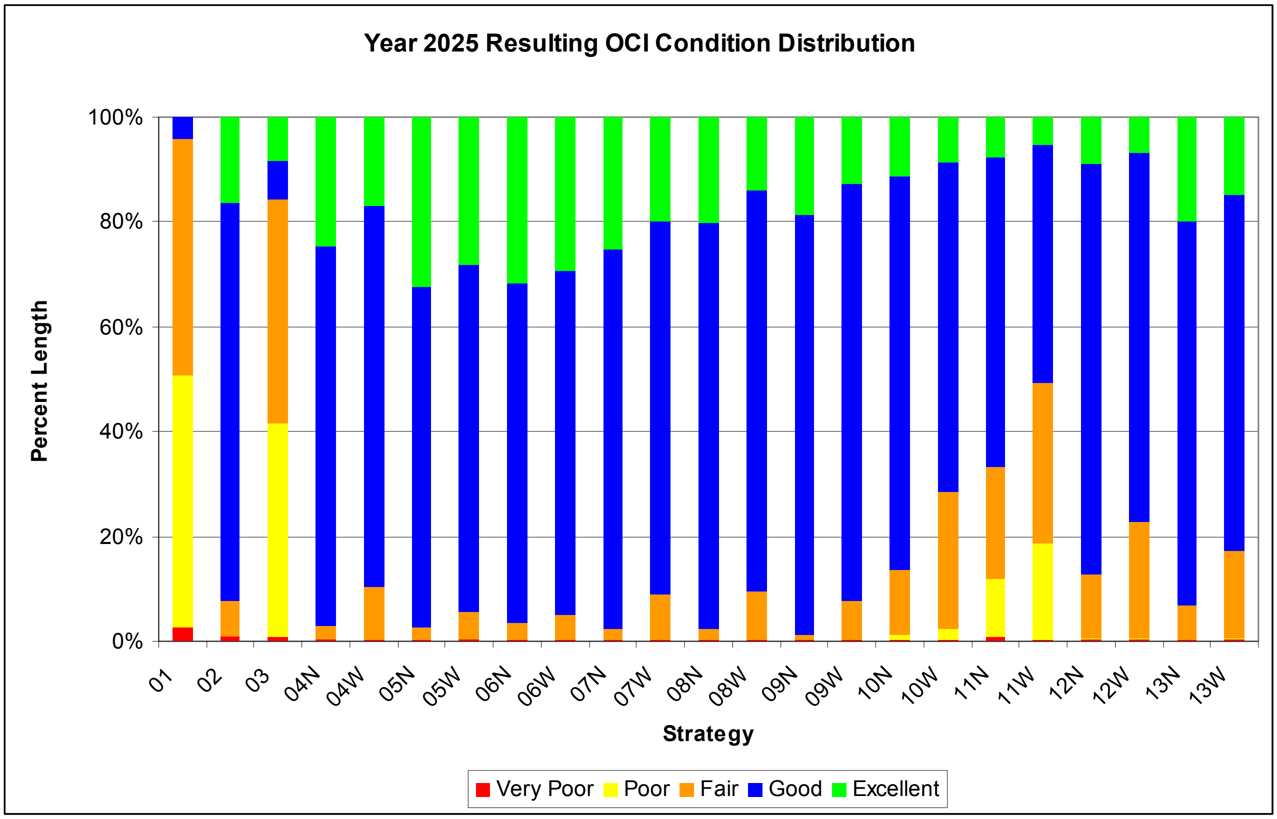


Figure 140: 2025 Resulting OCI Condition Distributions

In order to calculate these "looking forward" costs, the study examined the resulting condition distribution of each strategy and applied a cost based on the percentage of the network in very poor, poor, fair, good and excellent condition as follows:

- Very Poor roads would be reconstructed and then would receive a seal and finally a functional overlay.

- Poor roads would be reconstructed and then would receive a seal and finally a functional overlay.
- Fair roads would receive two rehabilitation treatments with the period from 2025 to 2045.
- Good roads would receive a seal and two functional overlay treatments.
- Excellent roads would receive one seal and one functional overlay treatment.

When these simple treatment strategies were applied to the condition distribution in 2025 from each of the strategies, the following "looking forward" costs were calculated:

Strategy	Very Poor	Poor	Fair	Good	Excellent	Strategty	2025 - 2045 Cost
01	2.61	48.14	45.04	4.21	0.00	01	$25,218,554,897
02	0.75	0.25	6.83	75.74	16.42	02	$6,516,860,694
03	0.74	40.73	42.93	7.25	8.34	03	$22,272,437,092
04N	0.20	0.00	2.83	72.40	24.57	04N	$5,555,177,643
04W	0.20	0.12	10.11	72.69	16.88	04W	$6,769,831,680
05N	0.20	0.00	2.41	64.97	32.42	05N	$5,296,462,532
05W	0.20	0.00	5.30	66.39	28.11	05W	$5,797,628,846
06N	0.20	0.00	3.31	64.62	31.87	06N	$5,432,603,597
06W	0.20	0.00	4.90	65.57	29.33	06W	$5,713,065,997
07N	0.20	0.00	2.07	72.58	25.15	07N	$5,437,467,774
07W	0.20	0.12	8.71	71.17	19.81	07W	$6,503,154,747
08N	0.20	0.00	2.05	77.59	20.16	08N	$5,562,643,311
08W	0.20	0.00	9.28	76.71	13.82	08W	$6,703,799,109
09N	0.20	0.00	1.09	80.08	18.63	09N	$5,472,719,808
09W	0.20	0.12	7.39	79.49	12.81	09W	$6,504,601,115
10N	0.20	0.90	12.59	75.00	11.30	10N	$7,455,240,509
10W	0.20	2.15	26.14	63.03	8.48	10W	$9,690,201,188
11N	0.95	11.03	21.23	59.03	7.76	11N	$11,579,085,112
11W	0.38	18.24	30.72	45.44	5.21	11W	$14,681,367,543
12N	0.20	0.34	12.09	78.54	8.83	12N	$7,300,929,393
12W	0.20	0.31	22.29	70.49	6.71	12W	$8,728,916,323
13N	0.20	0.12	6.49	73.38	19.82	13N	$6,203,122,672
13W	0.20	0.31	16.62	68.13	14.73	13W	$7,756,271,963

Table 85: 2025 - 2045 Looking Forward Costs

As can be seen in Table 85, the greater the percentage of the network in Fair, Poor and Very Poor condition, the greater the "looking forward" costs are to bring the network back to acceptable levels of condition. As the network condition worsens, the agency costs increase, which in turn leads to, increases in delay cost due to the reconstruction and major rehabilitation treatments being performed. The "looking forward" costs are another strong indicator of why good roads clearly cost less.

6.3 Do Good Roads Really Cost Less?

This study has clearly shown that a poor highway network impacts the economy and the citizens of Utah through increased accident costs, user costs, agency costs and delay costs as larger rehabilitation treatments are needed to restore the highway network to a good condition. Maintaining the network in good condition helps to reduce the impacts to the Citizens of Utah and citizens of other communities that are traveling the network.

Clearly, good roads do indeed cost less and as stewards of the public infrastructure, UDOT must maintain the highway network in good condition to minimize the impacts on the citizens of the state.

If UDOT did maintain the condition of the highway network at a lower overall OCI with significantly less expenditure over the analysis period an increase in accident costs and user costs would occur and the overall structural health of the network would suffer.

The strategies in the study allowed the resulting average condition of the network to vary greatly from highs of 85 OCI to lows of 50 OCI with expenditures ranging from a high of $4.8 billion to a low of $2.6 billion for the reconstruction only strategy.

If UDOT were to allow the system to deteriorate to a value of 50 over the analysis period, the difference in costs between the two levels of condition would be approximately $2.2 billion which is only 13% of the $16.5 billion of the unmet highway needs outlined in the Utah Transportation 2030 Long Range Plan. After that 20 year period was completed, UDOT's rehabilitation needs would continue to grow substantially as the network deteriorated into poorer and poorer condition as witness in the looking forward table of costs, Table 85.

The recommendation of this updated Good Roads Cost Less study is similar to the recommendation of the Good Roads Cost Less study in 1977. UDOT must strive to maintain the highway pavement assets in as good a condition as possible to minimize the impacts of the network to the citizens of Utah.

The preservation and rehabilitation dollars that could be diverted away from the program to fund capacity improvements would not be significant to impact capacity throughout the UDOT network. But that diversion of funds would have a significant impact on the highway network condition and its maintenance and rehabilitation needs in the future and on the user costs, accident costs and delay costs for the citizens of Utah using the highway network today. Clearly Good Roads Do Indeed Cost Less.

This conclusion and confirmation that Good Roads Cost Less is based upon the findings of the study and are summarized as follows:

- Pavements that are in good condition today can be maintained by an appropriate mix of minor maintenance, preservation and rehabilitation treatments that maximize the network OCI and prolong the life of the pavements.

- Pavements that are left to deteriorate to poor and very poor condition cause significant increases in accident costs, user costs, agency costs and delay costs.

- Pavements that are allowed to deteriorate to poor and very poor condition cannot be maintained through minor maintenance treatments as the treatment trigger mechanisms prevent inappropriate treatments taking place on pavements whose condition warrants a more extensive and expensive rehabilitation treatment.

- Pavements that deteriorate enough to bring the overall condition of the network lower by 20% or even by 10% can cause a funding crisis as the need for more expensive rehabilitation treatments raise the agency costs to the point where alternative funding solutions would be necessary.

- Current UDOT funding is sufficient to maintain the UDOT network in good condition but would be insufficient to restore the UDOT network to a good condition if the overall condition of the UDOT network were to deteriorate by as little as 10%.

- Diverting maintenance and rehabilitation dollars to support capacity enhancements (or other facilities or programs) will cause a deterioration of the road network overall condition throughout the analysis and would require a larger influx of money after the initial transfer of funds to restore the network to its current condition.

- When budget categories were used within the analysis, the resulting condition of the network was lower than the resulting condition when no budget categories were used even if no other parameters were changed. This leads to the recommendation that UDOT strive towards being more flexible in determining the funding for minor maintenance and rehabilitation treatments no matter the source of the funds.

6.4 UDOT Pavement Management Goals and Objectives

One of the goals of the Good Roads Cost Less study was to evaluate the pavement management system performance measures and goals for maintaining the UDOT highway network.

Within the asset management system, the analysis tends to focus on maintaining the current condition of each asset included within the system. Each of the individual asset groups overall condition indexes are monitored to ensure that the asset group does not deteriorate over the analysis time frame and that it is improved if necessary (depending upon the starting point of the index). Unfortunately at present, the system preservation goals and reporting mechanisms used by the pavement management team are not compatible with the information contained within the pavement management system.

In terms of reporting system condition, UDOT reports the condition of the network in terms of the Ride Index, based on half car IRI. This is based on a historic 1 to 5 scale with separate scales for asphalt and concrete pavements. The following list shows the half car IRI values used.

Qualitative Range	RI Index	Asphalt HRI	Concrete HRI
Very Good	4.35 to 5.00	0 to 42	0 to 79
Good	3.55 to 4.35	42 to 65	79 to 103
Fair	2.75 to 3.55	65 to 93	103 to 130
Poor	1.85 to 2.75	93 to 126	130 to 163
Very Poor	1.00 to 1.85	126 to 466	163 to 326

Table 86: Ride Index Performance Measure used to Report Pavement Condition

Performance goals have been set separately for the Interstate system, Arterial system and Collector system. These are to have 90% of the Interstate mileage at a Fair or better condition, 70% of the Arterial mileage at Fair or better, and 50% of the Collector mileage at Fair or better. The following chart shows a historic trend of the pavement condition reported with the RI.

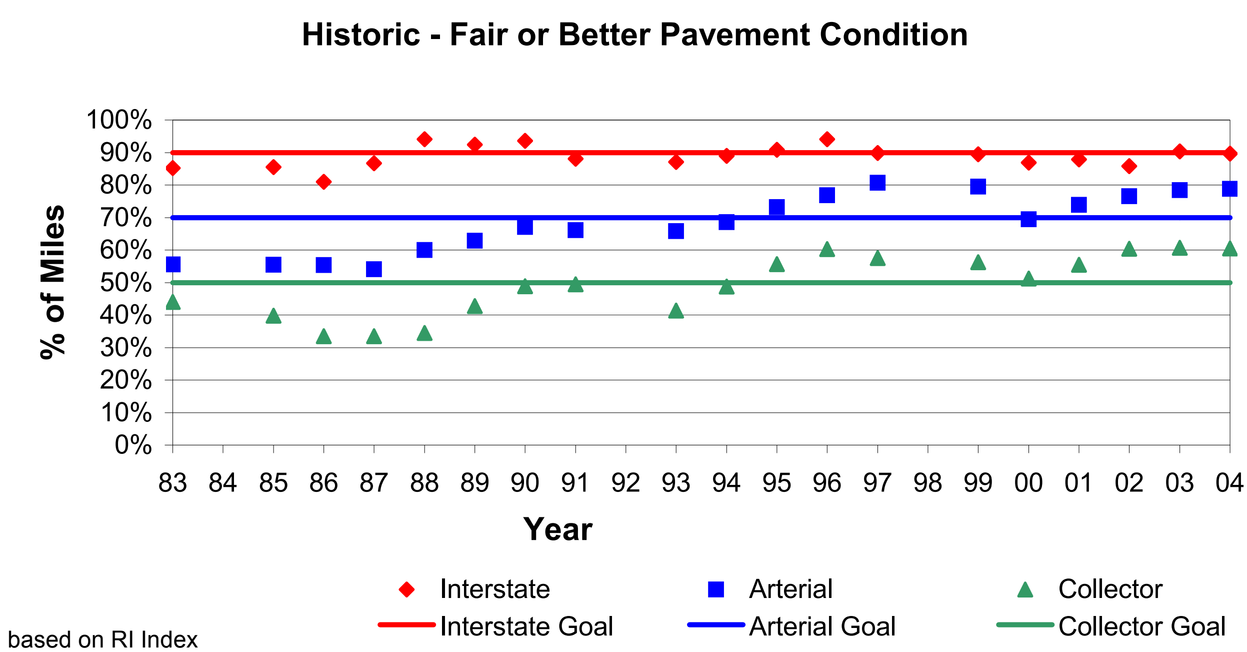


Figure 141: Historic Pavement Condition based on Ride Index

The issue with this reporting method is that the pavement management system and the asset management system do not have this index available within the system to use within the analysis and to report upon.

Therefore, it is very difficult to compare the results from the pavement management system with the current reported condition of the network and the results of the pavement management analysis can not be communicated to UDOT Senior Leaders, Utah Transportation Commission and the Utah State Legislature based on the current chosen reporting method using the RI based on Half Car IRI. This mismatch of indexes and goals can be seen by examining the System Preservation Goals figures within each of the strategy analysis result sections. From a network point of view, when the RI was examined for interstate, arterial and collector pavements and presented in graphical form, in each and every scenario except the do –nothing and the reconstruction only strategies, the reported system condition was above the stated goals. But, when the historic pavement condition is examined as shown in Figure 141, the reported measures do not exceed the system preservation goals as they do in the strategy analysis results.

What is needed for System Level Pavement Condition reporting is a single measure, using the same Index as used in the dTIMS model for analysis. This needs to provide the distribution of condition levels and not just report the percent fair or better.

6.5 A New Reporting Method for UDOT

In order to effectively communicate the condition of the UDOT Highway pavement network a new reporting method must be developed and implemented within UDOT that clearly and unambiguously indicates and describes the condition of the network to the UDOT stakeholders.

Currently, the condition of the pavement network is reported in terms of Percent Fair or Better which is an inadequate indicator of overall system health. For example a figure of 80% fair or better could mean 80% of the network is in fair condition, 80% of the network is in good condition, 80% of the network is in excellent condition or any combination imaginable.

A new reporting method for UDOT must clearly indicate at a glance the condition of the system and the approximate level of expenditure required to bring that system condition back to good condition.

The Good Roads Cost Less study team recommends that UDOT adopt a reporting mechanism called Good – Fair - Poor which indicates the percentage of the network in:

- Good Condition (requiring only minor maintenance and preservation treatments);
- Fair Condition (requiring only minor rehabilitation treatments);
- Poor Condition (requiring major rehabilitation and reconstruction treatments).

This reporting method clearly indicates the health of the network and also indicates the level of maintenance and rehabilitation treatments to restore the system to good condition. The Good – Fair - Poor reporting method can be used for any index included within the PMS and will also translate easily from the 1 mile sectioning to the PMS Project sectioning.

The Good Roads Cost Less study team recommends that the Good – Fair – Poor reporting method be used to report system condition using the IRI index. Separate reports will be generated for each system (Interstate, Arterial and Collector) and one overall Good – Fair – Poor report for the highway network. Separate Good – Fair – Poor reports will be generated as the performance goals for the highway network will no doubt be different for each system.

The study team also recommends that the PMS analysis be configured with the following performance measures:

- Structural Index – An indicator of the structural health of the network which will include fatigue cracking, rutting and deflection information.
- Surface Index – An indicator of the surface condition of the network which includes environmental cracking and in the future other surface distresses as data becomes available.
- Ride Index – An indicator of the riding quality of the pavement surface based on the average of the left and right wheel path IRIs.
- Skid Number – An indicator of the friction of the pavement surface to determine areas of the network to investigate but not necessarily to be included within the OCI.
- Remaining Service Life – An indicator of the health of the pavement in terms of its serviceable life. Again, the RSL may not be included within the OCI but used for reporting system condition within UDOT and to other supporting agencies such as the FHWA.

- Overall Condition Index – An indicator of the health of the pavement in terms of the averages of each of the other distress indexes.

Not all of these indexes are currently configured within the PMS and will need to be researched for inclusion.

If the looking forward condition distribution table is modified to show only three categories instead of 5, the Good – Fair – Poor graph of each strategy would look as follows:

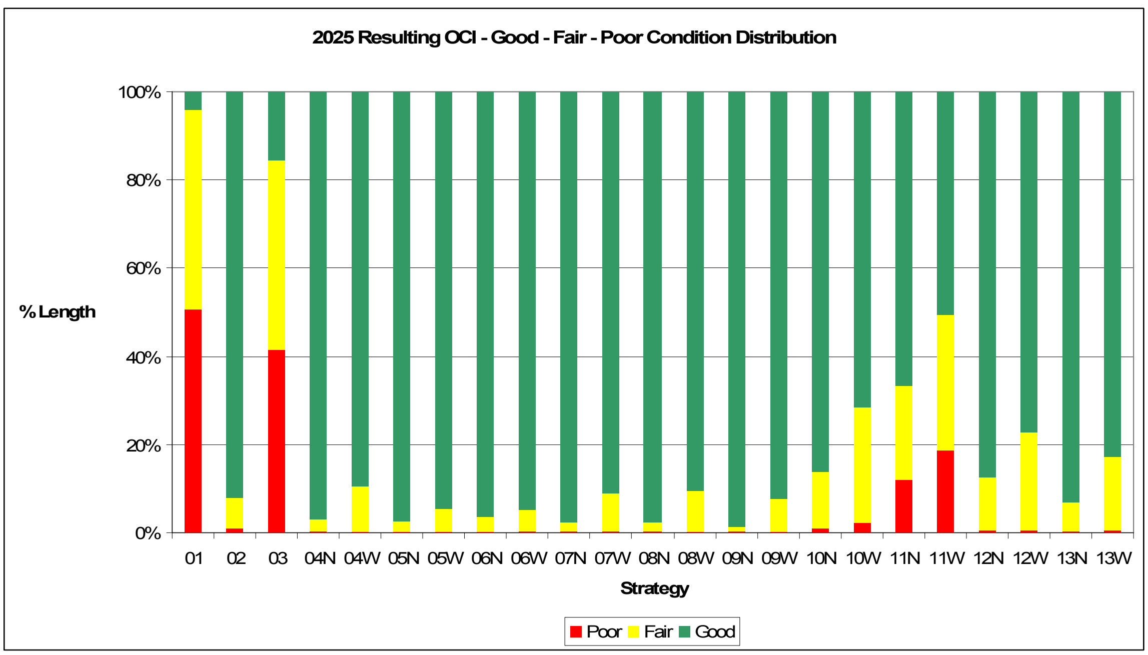


Figure 142: 2025 Resulting OCI - Good - Fair - Poor Condition Distribution

Strategy	Poor	Fair	Good
01	50.76	45.04	4.21
02	1.00	6.83	92.16
03	41.47	42.93	15.60
04N	0.20	2.83	96.97
04W	0.32	10.11	89.57
05N	0.20	2.41	97.39
05W	0.20	5.30	94.51
06N	0.20	3.31	96.49
06W	0.20	4.90	94.90
07N	0.20	2.07	97.73
07W	0.31	8.71	90.98
08N	0.20	2.05	97.75
08W	0.20	9.28	90.52
09N	0.20	1.09	98.71
09W	0.31	7.39	92.30
10N	1.10	12.59	86.30
10W	2.35	26.14	71.50
11N	11.97	21.23	66.80
11W	18.62	30.72	50.65
12N	0.53	12.09	87.38
12W	0.51	22.29	77.20
13N	0.32	6.49	93.20
13W	0.51	16.62	82.87

Table 87: 2025 Resulting OCI Good - Fair - Poor Condition Distribution

With this type of reporting, UDOT stakeholders can clearly determine and interpret the health of the system and the level of effort required to maintain the system.

6.6 UDOT Pavement Management Goals and Objectives Revisited

Various strategies within the study clearly showed that a deterioration of the system condition by amounts of 5%, 10%, and 20% in the overall condition of the network would lead to an increase in user costs, accident costs and an increase in necessary funding to bring the system condition back current system condition levels.

Various strategies also indicate that current UDOT funding is adequate to maintain the highway system in its current condition but not sufficient to increase the system condition if any deterioration of more than 5% occurs.

Therefore, quite simply, UDOT must maintain the overall system condition within 5% of its current condition in order to maintain that condition with current expenditures throughout the next 20 years.

Upon completion of this study, UDOT will investigate the goals for each of the systems (Interstate, Arterial, Collector and Network Wide) and present those goals to the Transportation Commission for approval.

6.7 Recommendations for Further Study

Throughout this study the researchers noted instances where further research by UDOT staff would be beneficial to the PMS and the AMS. These additional research topics and study areas are as follows:

- The treatment trigger mechanisms and the timing cycle of the Orange Book treatments require further investigation to ensure that Orange Book expenditures within the PMS match allocated budget so that no large surpluses remain when the analysis is complete.

- The costs and the benefits of each Orange Book treatment be investigated to ensure that the costs and the benefits of the treatments are accurately reflected in the PMS. It appears that the costs of the Open Graded Seal Coat treatment have risen significantly to make it a less cost effective alternative.

- UDOT investigate the creation of a Structural Performance Measure to indicate the health of the pavement structure.

- UDOT investigate the creation of a Surface Condition Performance Measure to indicate the health of the pavement surface.

- UDOT investigate the recommended System Goals from the study and approve and adopt those goals.

- UDOT investigate pavement sections throughout the network that have weak subgrades and that are carrying loadings greater than those accounted for in the pavement design. These sections might be indicative of early pavement failures and could be modeled within the PMS and the AMS.

- UDOT develop an effective means to inventory, store and manage historical construction projects to track changes in the pavement network due to constructions and jurisdictional transfers.

- UDOT investigate the use of “spring load restrictions” for the highway network where appropriate and include those locations within the PMS and within the PMS models if required.

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