WEIGHT FACTOR DETERMINATION AND FUND ALLOCATION OF PAVEMENTS BY COST BENEFIT ANALYSIS

by

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ABSTRACT

CHAITALI RAMAKANT PATIL. To determine the benefit weight factors and allocate maintenance funds for pavements using Cost-Benefit Analysis. (Under the direction of DR. DON CHEN)

The purpose of this study is to determine the most efficient and ideal weight factors by performing the Cost-Benefit Analysis (CBA) using the North Carolina Department of Transportation's (NCDOT) Pavement Management System (PMS) and using the ideal weight factors. Constraints such as treatment cost, NCDOT Rating Number and Budget Group is considered while performing the CBA in the PMS. There are thirty-three sets of weight factors and each one is analyzed by performing CBA for 5 years, for 14 Divisions and four systems, i.e., Interstates, U.S, NC & Secondary Routes (SR). The ideal weight factors are the ones that yield the least total treatment cost. Then using the ideal set of weight factors, the CBA is performed for all the 14 Divisions individually once again, and the project cost for the four system is calculated. The percentage of funds to be allocated for each Division according to the fund types and regional classification is calculated. This framework will help in allocating the maintenance funds according to the systems and its Division for a specific year. Such analysis can be used in identifying the most effective and cost-saving treatment for a roadway network and the available funds can be utilized in such a manner that maximum benefit can be achieved.

DEDICATION

This thesis is wholeheartedly dedicated to my parents who have been my source of inspiration and strength, who provided me moral and an emotional support. It is also dedicated to Dr. Don Chen and all the professors from the Williams State Lee College of Engineering who shared their words of advice and helped me to finish this study.

ACKNOWLEDGEMENTS

I would such as to thank the Almighty for giving me the strength, patience, and love for all the support during my graduate studies. I would also such as to thank my parents, Bharti and Ramakant Patil, for always being with me when I needed them the most. And last, but certainly, not the least, I would such as to thank Dr. Don Chen and his trust on me. I would not be able to complete my study without his teaching and faith in me. He always encouraged me to be a better person in terms of knowledge and hard work. He has and will always be a source of inspiration for me. I have been blessed to work as a Graduate Research Assistant under him. He has been the best mentor I could ever ask for. I am thankful for everything he has performed for me.

I would such as to express my deepest thanks to the North Carolina Department Of Transportation for believing and supporting this research project.

I would such as to express my sincere gratitude and appreciation to all the professors, faculty, and staff member in the Williams State Lee College of Engineering. The encouragement, knowledge, hard questions and comprehensive advice I have received from them have shaped me into the student I am today. I will always remember the time I spent here in UNC Charlotte and will never forget the students, professors, and staff that has made a positive impact on my life.

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LIST OF ABBREVIATIONS

AASHTO	American Association Of State Highway And Transportation Officials
CBA	Cost-Benefit Analysis
HMA	Hot Mix Asphalt
IRI	International Roughness Index
LCCA	Life-Cycle Cost Analysis
NC	North Carolina
NCDOT	North Carolina Department Of Transportation
NPV	Net Present Value
OPCI	Overall Pavement Condition Index
PCI	Pavement Condition Index
PMS	Pavement Management System
PSR	Present Serviceability Rating
RI	Roughness Index
RQR	Ride Quality Rating
RSL	Remaining Service Life
SR	Secondary Routes
TIP	Transportation Improvement Program
U.S.	United States
MAE	Maximum Allowable Extent

CHAPTER 1: INTRODUCTION

This report presents the method of finding the ideal set of weight factors by performing a Cost-Benefit Analysis (CBA) using the North Carolina Department Of Transportation's (NCDOT) Pavement Management System (PMS) and then using the ideal set of weight factors for the fund allocation for roadway network systems. This framework will help its users to perform a more efficient CBA and allocate funds appropriately (Chen, 2014). The North Carolina Highway System is operated by the NCDOT which consists of a vast and widespread network of Interstate, U.S., NC, and SR roadways. In 1915, when N.C. General Assembly created the State Highway Commission, North Carolina had just 1,200 miles of paved roads.

In the U.S., the NCDOT today is managing one of nation’s most responsible and extensive highway system. The total of modern interstates, U.S. and N.C. routes make up nearly 80,000 miles of roadways. From planning to building and maintenance, the Division of Highways is responsible for all the aspects related to its state's highways and roadsides. Their main goal is the proper and safe movement of traffic (NCDOT: Highway Sections & Units,2018). For achieving this goal, the NCDOT has divided these responsibilities across the state into 14 Divisions. They are called highway Divisions which are supported by various units and sections within the Division of Highways. The NCDOT divided the duties of maintaining and building the state-owned bridges and highways. Figure 1 (N.C. House, District 117) shows the NCDOT's 14 Divisions.

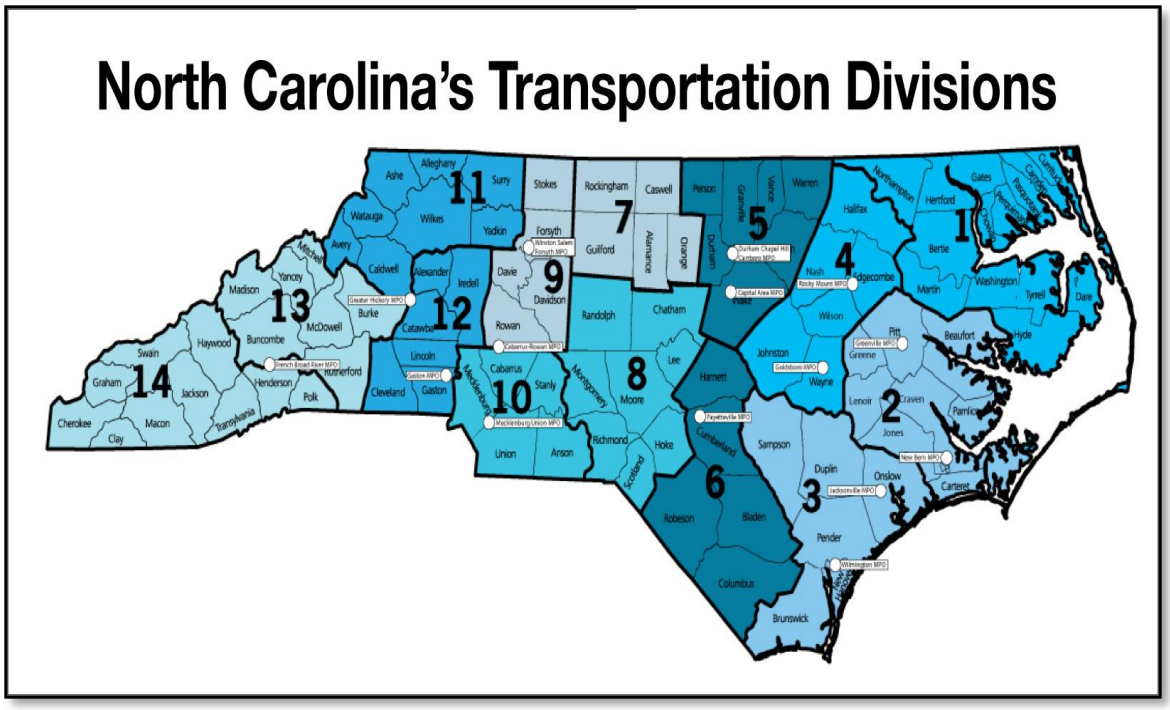


Figure 1: NCDOT's Transportation Division

The NCDOT manages various sections and units under the Division of Highways that work together to build and maintain state-owned bridges and highways including:

- Administrative Services
- Maintenance & Operations
- Technical Services
- Transportation Mobility & Safety

1.1 Maintenance & Operation

The NCDOT's Division of Highway which manages the maintenance and operation section has divided its responsibility further across the state into various units which helps them to maintain the bridges and roads. Figure 2 shows the various sections included under Maintenance and Operation (NCDOT: Highway Sections & Units):

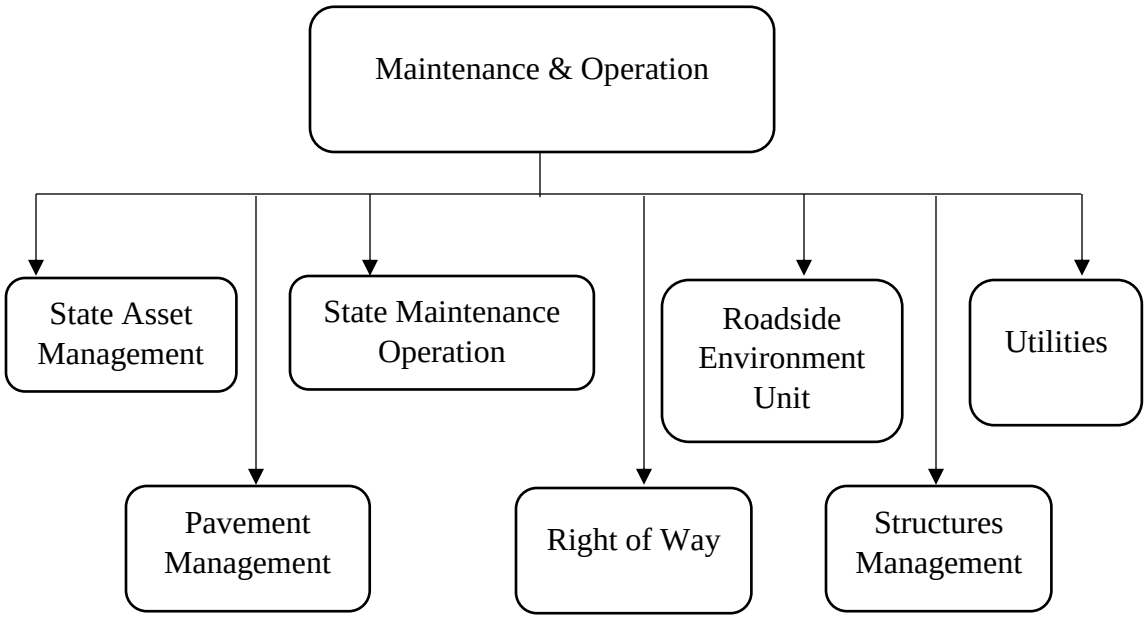


Figure 2: Types of Maintenance & Operation

The NCDOT's Pavement Management section comprises of three main activities (NCDOT: Highway Sections & Units):

- Collecting data on roadway pavement to determine its condition
- Developing designs for the pavements on new highways and existing pavements that need to be replaced or improved.
- Maintaining the Pavement Management System database and reports that help determine needs.

1.2 Problem Statement

The main goal of this study is to determine the benefit weight factors by performing the CBA using the NCDOT's PMS for allocating the maintenance budget for the future pavement maintenance planning.

1.3 Research Purpose

A CBA is usually conducted for making economic decisions using various alternatives available. In this study, a CBA was used for selecting the most economical alternative amongst various pavements treatment types using the NCDOT's PMS. By maximizing benefits, better investment decisions for pavement maintenance, preservation, rehabilitation, and replacement can be made by obtaining maximum benefits.

Generally, for treating the pavements, its condition is checked and then a suitable treatment type according to the budget of the NCDOT is selected. The funds are divided accordingly to the systems and Divisions. In this study, four systems, i.e., Interstates, U.S., NC, and SR were considered.

The primary purpose of this research was to find the ideal set of weight factors by performing the CBA and then allocating the maintenance funds according to the types of fund for each system and Division. By performing the CBA of the systems for a span of five years, the treatment type and its treatment cost can be found. For running the CBA, a set of 33 weight factors is used for 14 Divisions and 4 systems (Chen, 2014). After the CBA is performed for all the 14 Divisions, regression analyses were conducted to obtain the relationships between the benefits and weight factors. Five new sets of weight factors were obtained based on these relationships. A CBA was performed for those set of weight factors again and the weight factor having the least treatment cost was selected as the ideal weight factor. After selecting the ideal weight factors, a new cost-benefit analysis was performed for dividing the funds according to three types, i.e., Fund I which consists of Interstate maintenance, preservation and resurfacing, Fund II which consists of contract resurfacing for U.S., NC and SR and Fund III which consists of pavement preservation for U.S., NC and SR. Figure 3 represents the above-explained procedure.

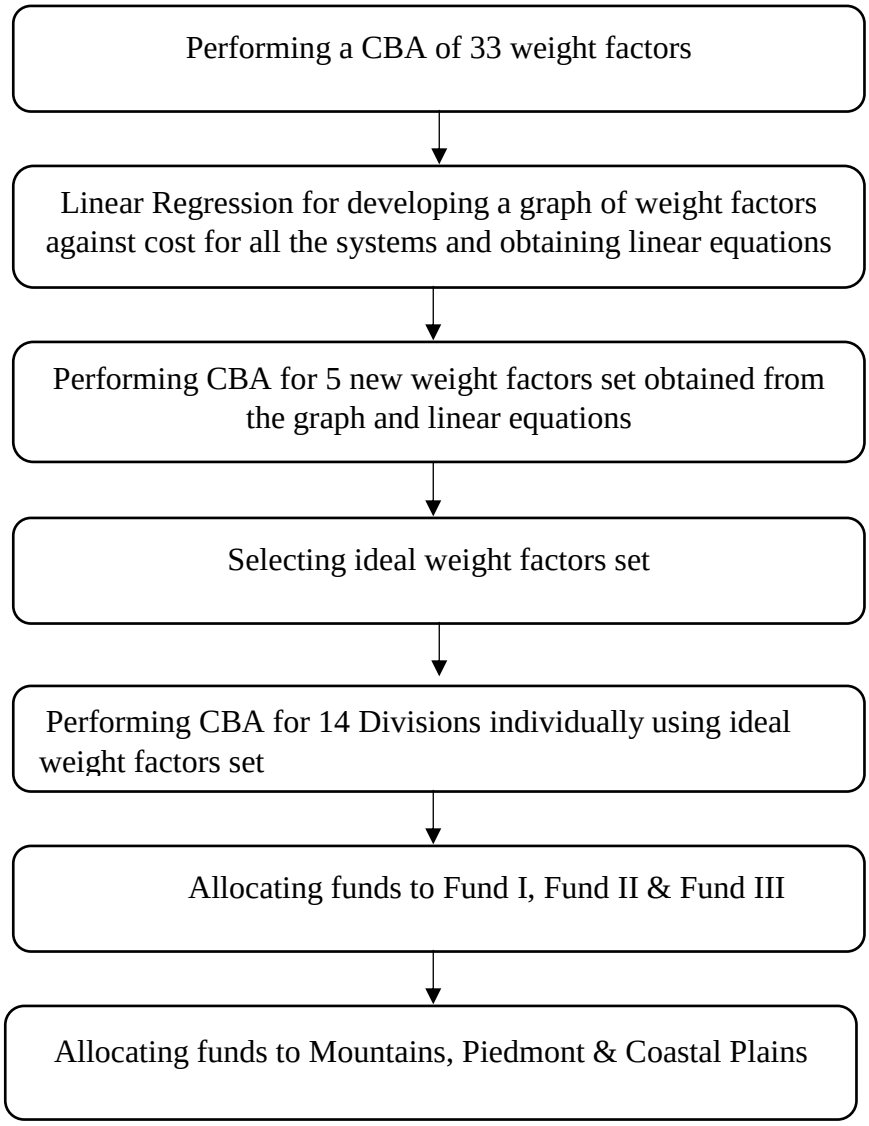


Figure 3: Flowchart of Research Methodology

After finding the total maintenance cost for each fund type, further fund allocation was conducted according to the regions. North Carolina is divided into 3 geographical regions i.e. the Mountains, Piedmont and the Coastal Plains. Funds

allocations for the Divisions included in these regions was performed and graphs were developed for showing the fund distributions according to maintenance need.

The funds that the NCDOT receives annually were categorized into three types, for Fund I which includes the Interstates maintenance, the Fund II which includes contract resurfacing for U.S., NC & SR and Fund III which includes pavement preservation for U.S., NC & SR. Figure 4 shows the representation of the these three funds.

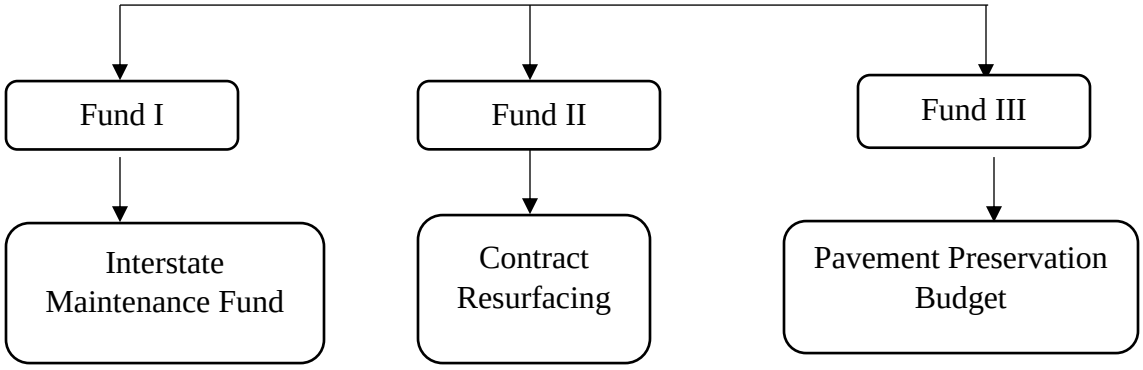


Figure 4: Types of Fund

1.4 Fund Allocation in Pavement Management System

The main question every agency has is the fund allocation of the available funds which involves level of coordination among the various management system (AASHTO, 2001). With the help of the prioritization and optimization procedures, the problem of identifying the best sections of pavements to repair with limited funding can be solved. According to the Pavement Management Guide published by American Association of State Highway and Transportation Officials (AASHTO), the allocation is the Division of funds among different groupings including (AASHTO, 2001):

- Functional classification (Interstate, U.S.);

- Subregions (districts) within the agency's area of responsibility;
- For some agencies, among different jurisdiction levels (city, county, and state).

The fund allocation analysis should be able to show how allocating funds to the different classifications will help in changing the overall benefits to the using public. Many agencies include the maintenance and rehabilitation strategies based on PMS analysis results in their allocation formulas (AASHTO, 2001).

In North Carolina, nonstructural improvement activities (routine and preventive maintenance) are the responsibility of geographic Divisions (AASHTO, 2001). Typically, a Division will use the pavement condition report to select pavements in each county which need maintenance or treatment and prioritize them according to pavement conditions and traffic volume. For structural improvement projects (rehabilitation and reconstruction), which are included in the Transportation Improvement Program (TIP), the PMS develops the priority list based on pavement condition and reasonable project length to establish project limits. The priority list prepared is based on the pavement condition, Division, cost, and Division funding.

1.5 Importance of Pavement Management System

A PMS is a set of tools used to assist decision-makers at all levels in making better and more informed decisions (AASHTO, 2001). In preventive maintenance, treatments are applied to prevent or reduce the rate of deterioration of the pavements. Pavement management practices provide a rational approach to assist in finding a cost-effective combination of treatments to apply at right time to provide the level of service selected by the managing agency. Various maintenance and rehabilitation strategies are developed which can lead to the desired outcome. Pavement management also provides

information about the funds' request and justify maintenance and rehabilitation programs. Pavement management is generally described, developed, and used in two levels network level and project level (AASHTO, 2001). There are many differences between both types of pavement management levels in terms of the project size, organization and other factors involved. Figure 5 shows the different goals of each pavement management level (AASHTO, 2001).

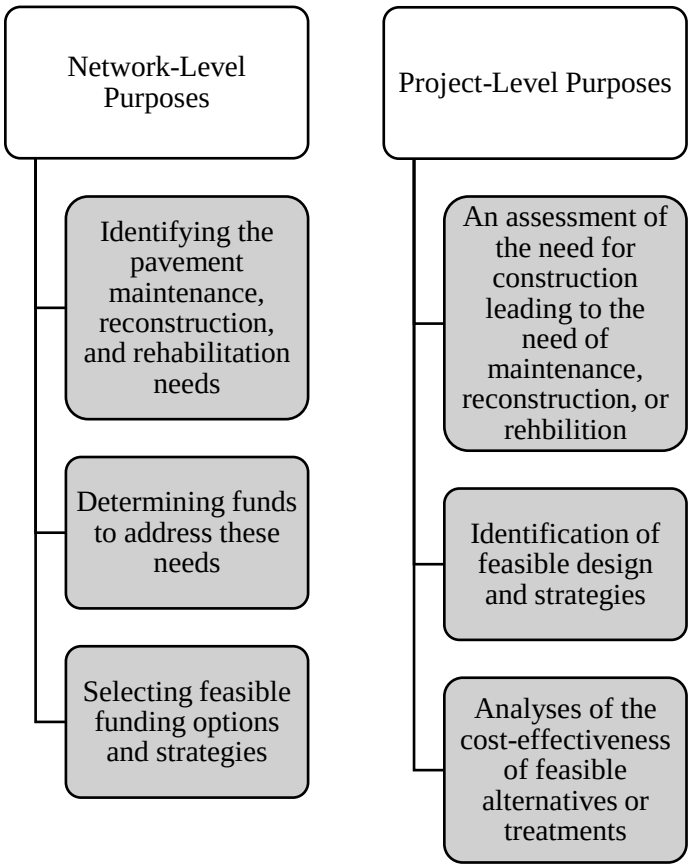


Figure 5: Pavement Management Levels

At the network level, the decisions are made within the organizations, and they generally have some level of authority in allocating the specific funds being managed whereas at project level the decisions about which segment should be funded are made (AASHTO, 2001).

1.6 NCDOT's Pavement Management System

The CBA function in the NCDOT's PMS can provide the following end results ("Pavement Analyst", 2018):

I. To preview investment outcomes
   - Many scenarios can be created for achieving a specific performance target or to see budget allocation for gaining maximum benefits.

II. To optimize work plans
   - Projects can be aligned across many years for creating an efficient work plan which will help in reducing efforts and saving money.

III. For improving management strategies
   - Work plans can be created using a predictive modeling technique for determining the best time to apply a preventive treatment that helps in keeping the pavement in a good repair condition.

IV. To generate precise reports
   - Interactive results can be produced that will show the effects of the investment decisions.

CHAPTER 2: LITERATURE REVIEW

2.1 Cost-Benefit Analysis (CBA)

Previous studies on the application of CBA for pavements have been performed by applying various analysis methods and cost-effective treatments alternatives. In 2012, a CBA was performed for selecting the most economical alternative among various pavement preservation choices using the life-cycle cost analysis analytical method (Wang et al. 2012). In this study, pavement performance curves were developed for various treatments under different pavement condition levels at each traffic level based on Overall Pavement Index (OPI) data of the Pennsylvania Department of Transportation. A relationship was developed between pavement life extension and pavement condition before the treatment. Least Cost Cycle Analysis (LCCA) was performed to identify the effect of the pavement condition on the performance of the preservative treatments in terms of cost-benefit ratio and net equivalent uniform annual cost. It was found that crack sealing has the highest cost-benefit ratio whereas NovaChip has the least cost-benefit ratio. Also, treatments applied very early add less benefit and treatments applied too late are ineffective.

Combination of the factors of pavement residual values and maintenance input was performed cumulatively and a new economic-benefit index and an economy-benefit model concerning time increasing benefit and three maintenance treatments were developed and evaluated (Zhou et al. 2013). Analysis of the reasonable indicator of

preliminary maintenance cost analysis to provide the reference for asphalt pavement preventive maintenance cost-benefit analysis. Techniques applied for asphalt pavement preventive maintenance are crack filling, crack sealing, fog seal, crushed stone seal coat, slurry seal coat, micro surfacing, hot asphalt overlay and milling thermal shop. "Economic-Benefit" evaluation model was developed.

In this study, Net Present Value, Residual Value, Daily maintenance cost and investment fee of maintenance was considered. A term called the economic capability of different maintenance technologies was introduced which is based on the mean and standard variance results in better maintenance technologies. A higher mean value and lower standard variance result in better maintenance technologies. The economic analysis for three kinds of technologies such as hot asphalt overlay, micro surfacing, and the thermal milling shop was performed. There was a difference between the three maintenance technologies. Micro surfacing had the highest economic benefit ratio than others which had second investment. Therefore, micro surfacing has a better economy than others, and it can be considered in future conservation switch.

2.2 Pavement Management

In this study, International Roughness Index (IRI) and Pavement Condition Index (PCI_ were used to perform pavement management assessments (Arhin et al. 2015). It was found that the composite pavements were smoother than Asphalt pavements followed by concrete pavements.

Pavement smoothness or roughness can be expressed as the extent of the non-existence or existence of surface irregularities that affect the ride quality of road users (Arhin et al. 2015). By using a road profiler which produces a series of numbers to represent the profile of the road by taking elevation and height into consideration. The data were

screened based on the expectation that a high IRI value should correspond to a low PCI value and vice versa (Arhin et al. 2015). The residuals are the differences between the observed variables and the predicted values using the regression function developed. The model fits the data poorly if non-random structure is formed. It was concluded that all pavements experience an increase in distresses out of which composite pavement had less distresses than concrete and asphalt.

The maintenance and rehabilitation of pavements and how the pavement performance is evaluated using pavement condition indicators by the Pavement Management System was studied by Shah et al. (2013). Commonly used pavement indicators are Pavement Condition Index (PCI), Present Serviceability Rating (PSR), and Roughness Index (RI). For the selected network of roads, a combined Overall Pavement Condition Index (OPCI) was considered and used in selecting maintenance strategies for pavement section. The data was collected from visual inspection as well as construction and maintenance records. The distress index was calculated by using the principle of Maximum Allowable Extents (MAE). The riding quality of the pavement depends on the smoothness of the pavements, and it was rated on a scale of 0 to 100 as the Ride Quality Rating (RQR).

Benkelman Beam technique was used, and a threshold index value of 60 was taken which indicated that the pavements need repair. It can be observed that the inclusion of a condition indicator to the previous PCI for each road degrades the pavement condition (Shah et al. 2013). Therefore, it can be concluded that OPCI provides a real indication of the pavement condition inclusive of all functional and structural defects. The treatment type to be applied depends upon factors such as road class, surface type, and pavement

condition index. It can be concluded that the multi-indices indicators are more reliable and appropriate in selecting the treatment.

A pavement performance decay model was developed which helped in pavement preventive maintenance management system (Bai et al. 2013). The developed model is applicable for maintenance funds decision analysis.

Six pavement conditions indexes from five DOT's in the United States were compared based on distress and ride quality data (Gharaibeh et al. 2009). The computed data was compared visually using scatter plots and analyzed statistically with paired t-test. All the pavement condition indexes were computed by using different formulae and scatter plots were developed for all indexes. Then a paired t-test was conducted to see whether there is a significant difference between the means of all indexes. Indexes that consider roughness in an addictive manner are less impacted by excessive roughness than ones that consider roughness in a multiplicative manner (Gharaibeh et al. 2009). Therefore, it can be concluded that significant differences exist among these similar pavement condition indexes.

2.3 Remaining Service Life (RSL)

The RSL is an estimate of the time from analysis point until the condition of the pavement is projected to reach an acceptable condition (Baladi Gilbert and Novak Jr Edwin 1992). In RSL, below a certain limit, the pavement is considered having no remaining life. It is the level where the pavement can carry the traffic but cannot provide the minimum Acceptable level of service. PMS helps in calculating the RSL of any pavement sections by subtracting the ongoing year from the year in which the pavement section is assumed to reach the lowest level of its service life. If the average remaining service life increases with

a funding scenario, the time until major work will be required is getting larger (AASHTO, 2001).

The condition level which is set for the pavements is termed as Pavement Condition Index. It usually ranges from 0 to 100. 100 is the level where the pavement is just constructed and is at its best working condition. Usually, when the PCI value reached 60, the pavement is considered for rehabilitation. Following Table is an example of the PCI level and the maintenance work showing to be performed at a PCI.

Table 1: PCI Values

PAVEMENT CONDITION INDEX	TREATMENT
100-80	Corrective/Preventive Maintenance
80-60	Light Rehabilitation
60-40	Moderate Rehabilitation
40-0	Reconstruction

Figure 6 shows the graph plotted against the remaining service life or age of the pavement and the Pavement Condition Index (AASHTO, 2001).

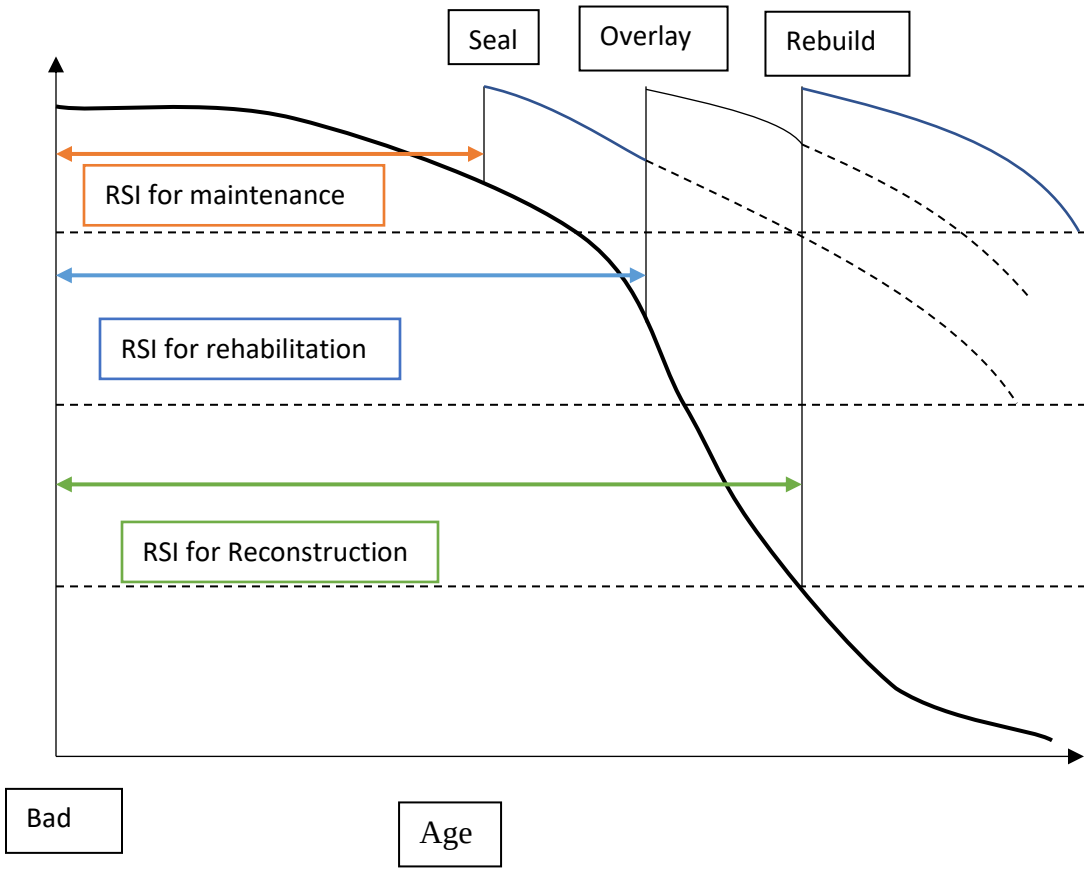


Figure 6: Remaining Service Life Graph

CHAPTER 3: RESEARCH METHODOLOGY

This chapter describes the essential steps that were taken to determine the ideal set of weight factors for performing the CBA and allocating the funds according to different fund types and roadway classification. The steps are as follows:

Step 1: The CBA was performed using 33 sets of weight factor sets by considering the 14 Divisions and 4 systems in North Carolina. The analysis period is 5 years. Constraints such as treatment cost and NCDOT Rating Number were activated in the NCDOT's PMS for finding the total project cost for a specific Division.

Step 2: Results of the 33 CBA analyses were studied and the total treatment costs were compared. Linear regression was performed between the treatment cost and three systems, i.e. Interstates, U.S. and NC. Three linear equations were derived, and a graph was plotted using those resulting equations. No linear regression was conducted for SR routes because its weight factor value being set to a constant value of 1.0.

Five new weight factor sets were obtained, and a CBA was performed again. The set having the least treatment cost was selected as the ideal set of weight factors.

Step 3: A CBA was performed using the ideal weight factors set for the 14 Divisions individually. It was performed for 5 years and 4 systems. After performing CBA, funds were allocated for all Divisions according to the three fund types. Constraints such as treatment cost and NCDOT Rating Number were used.

Step 4: Funds allocation was performed according to the regional classification such as the Mountains, Piedmont, and the Coastal Plains. All the Divisions were subcategorized according to the regions and funds were allocated by each fund type and its treatments.

Graphs were developed for each region according to the fund types. Figure 7 shows the flowchart for the steps involved in performing fund allocation:

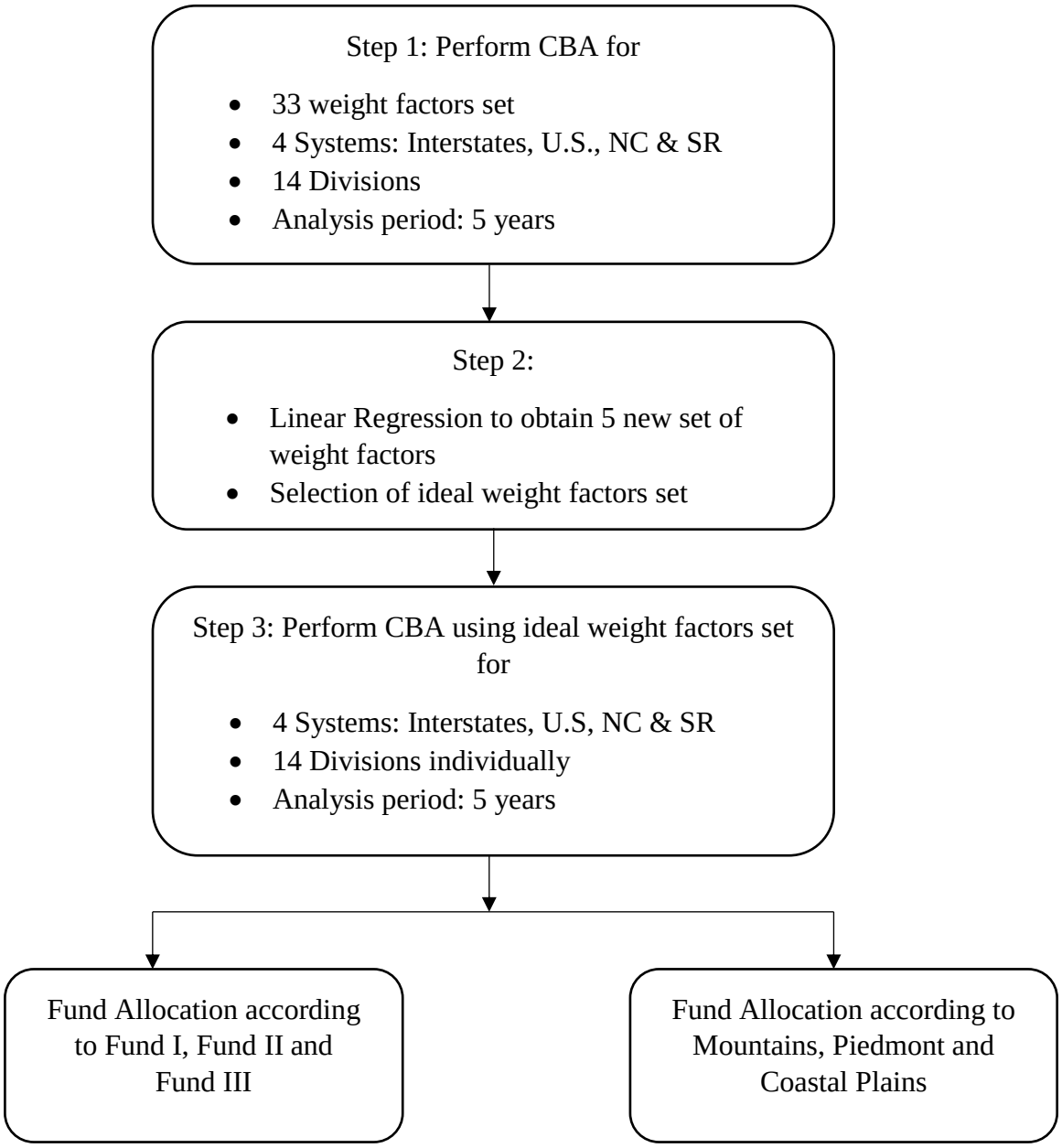


Figure 7: Research Methodology

3.1 Weight factors and CBA Scenarios

This section discusses the 33-weight factor sets used for conducting the CBA. It gives further vision for calculating the ideal weight factor set which will be used for allocating funds. The 33 weight factors set can be seen in Table 2 (Chen, 2014).

Table 2: Weight Factors

Interstate	US	NC	SR
2.0	1.7	1.3	1.0
1.3	1.2	1.1	1.0
3.0	2.7	2.3	1.0
1.8	1.4	1.2	1.0
2.9	1.5	1.3	1.0
2.4	2.1	1.8	1.0
2.7	2.1	1.4	1.0
2.1	1.8	1.1	1.0
2.2	2.0	1.8	1.0
2.7	2.3	2.0	1.0
2.9	1.4	1.3	1.0
2.6	2.4	1.6	1.0
2.0	1.5	1.2	1.0
2.9	1.7	1.1	1.0
1.9	1.4	1.3	1.0
2.9	2.5	1.7	1.0
1.8	1.7	1.5	1.0
2.9	2.6	2.1	1.0

2.6	1.5	1.3	1.0
2.8	2.5	1.3	1.0
3.0	2.6	1.6	1.0
2.8	2.4	1.4	1.0
1.9	1.8	1.1	1.0
2.5	2.2	1.3	1.0
2.2	2.1	1.3	1.0
2.8	1.7	1.3	1.0
2.4	2.0	1.3	1.0
2.3	2.1	1.9	1.0
3.0	2.6	1.2	1.0
3.0	1.9	1.7	1.0
2.4	1.8	1.3	1.0
2.2	1.8	1.2	1.0
1.7	1.4	1.3	1.0

Using the PMS, 33 CBA scenarios were generated and performed for each weight factors set. Constraints such as treatment cost and NCDOT rating number were used. For the NCDOT Rating Number constraint, sub-constraints such as “budget group by system” and “budget group” were selected. By selecting these constraints, the information about the treatment types and its cost, NCDOT rating number and the total benefits per year were obtained. Figure 8 shows the homepage for the NCDOT PMS.

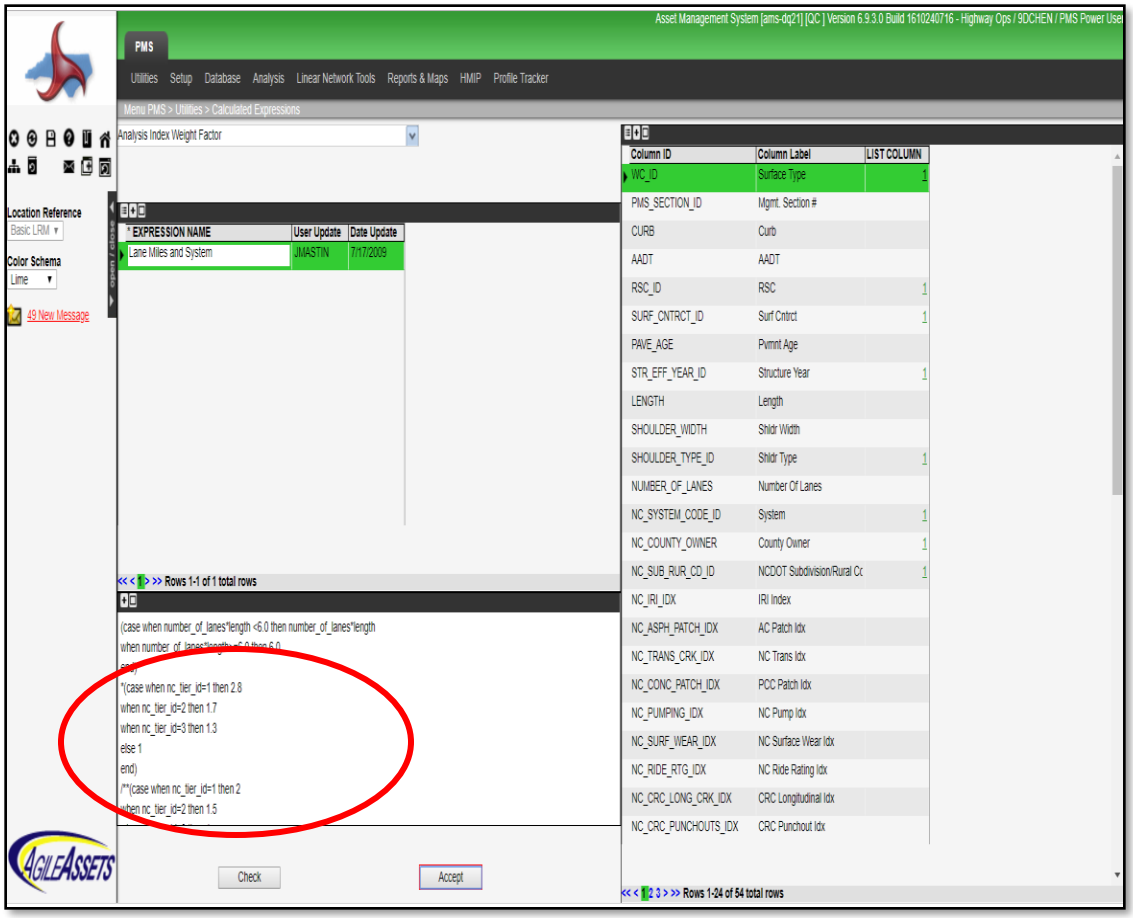


Figure 8: PMS Homepage

Figure 9 shows part of the PMS where the weight factors are inserted every time for running one CBA. In this case, the weight factor for Interstates is 2.8, 1.7 for US, 1.3 for NC and 1.0 for SR.

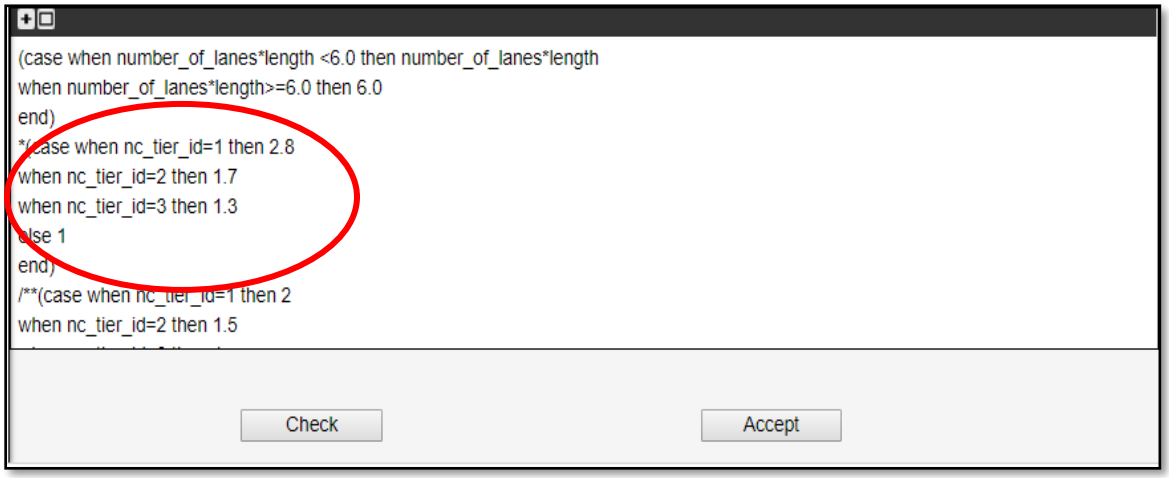


Figure 9: Weight Factors

Figure 10 shows the page where all the CBA scenarios are generated and performed

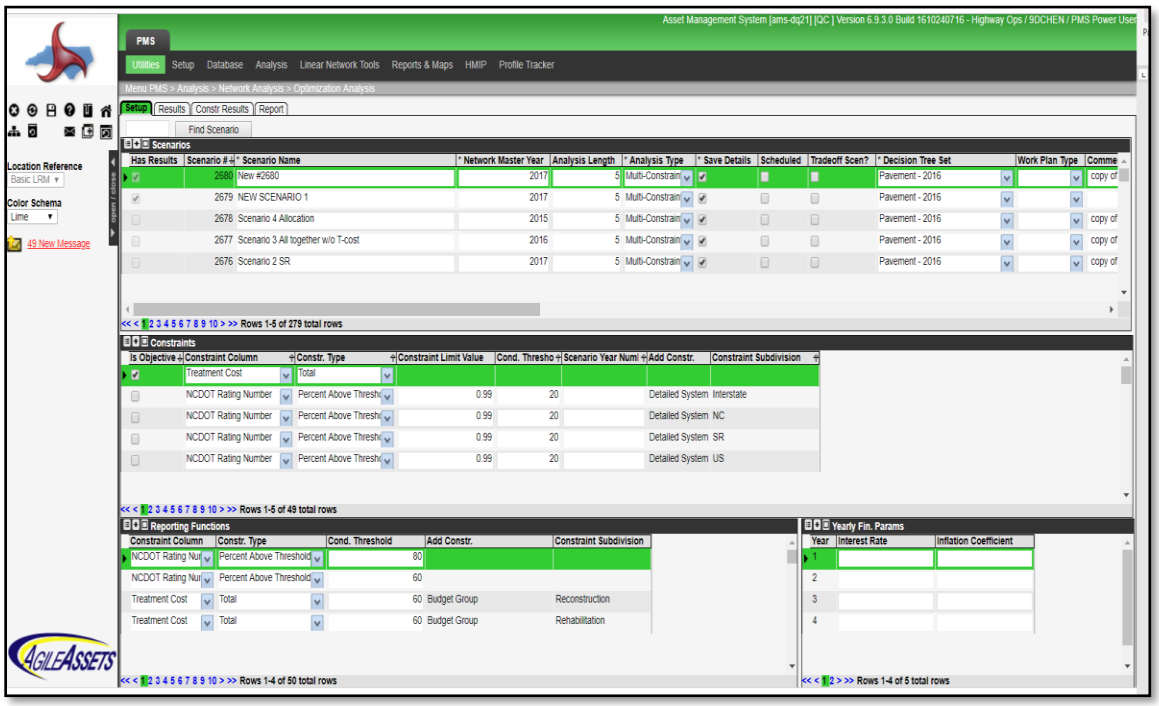


Figure 10: Optimization Analysis

After creating a CBA scenario, its scope is changed according to the Divisions and the systems used for running it. The number of Divisions selected for running the CBA is displayed in Figure 11.

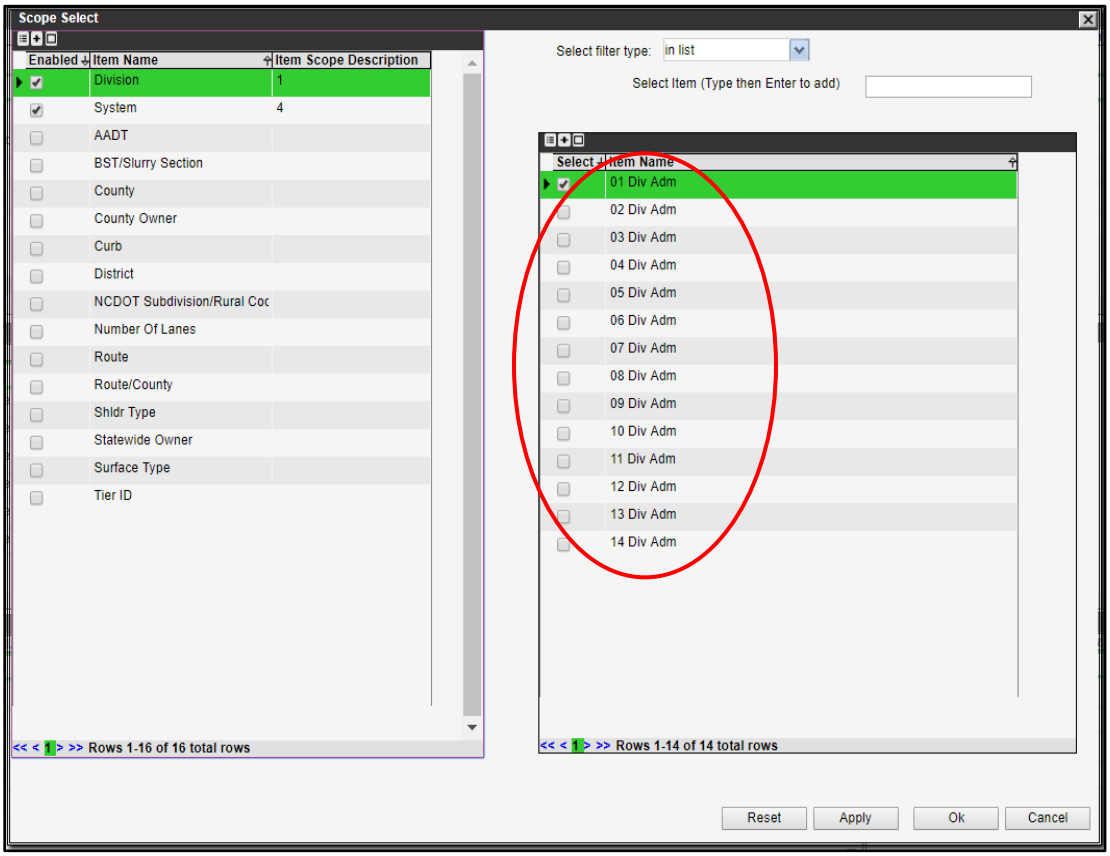


Figure 11: Division Selection in PMS

Figure 12 shows the systems selected for the CBA scenarios which are Interstates, US, NC, and SR.

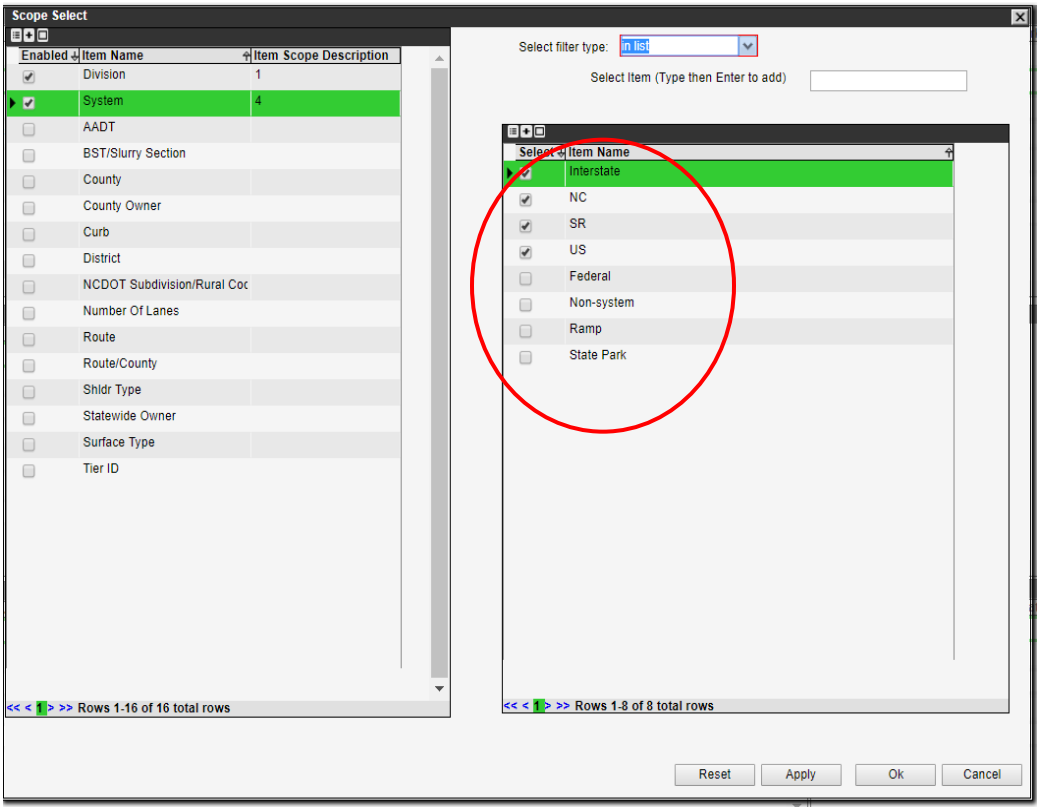
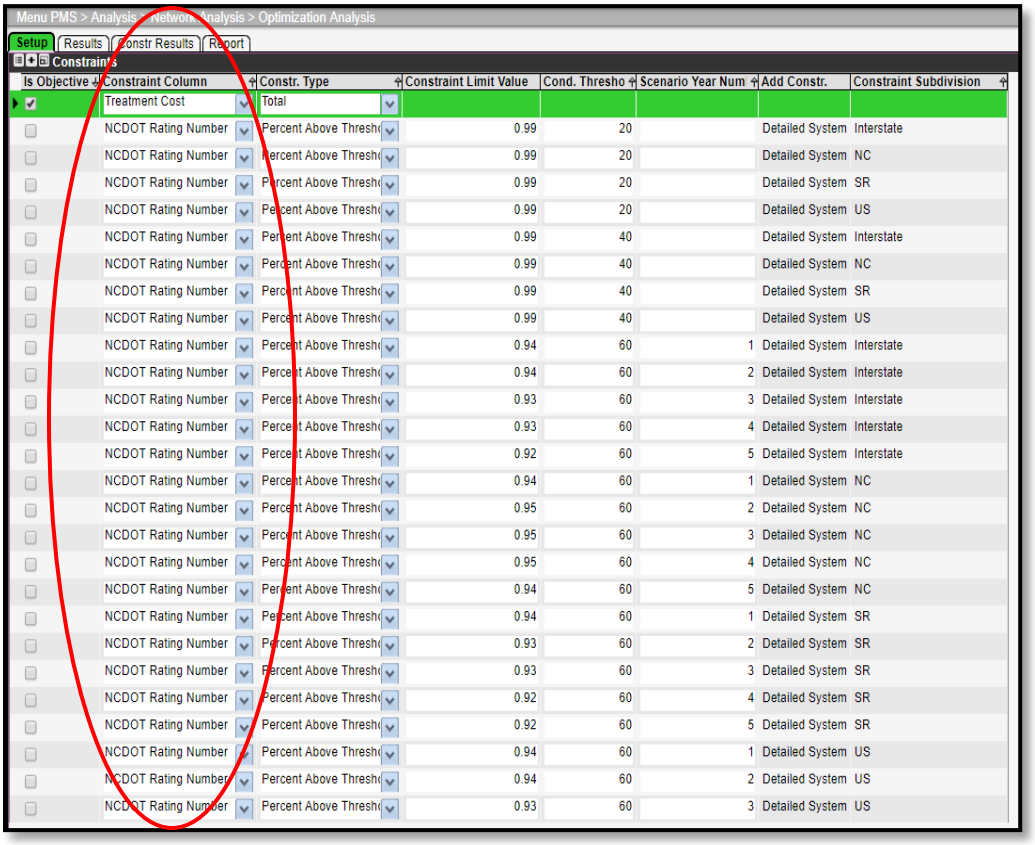


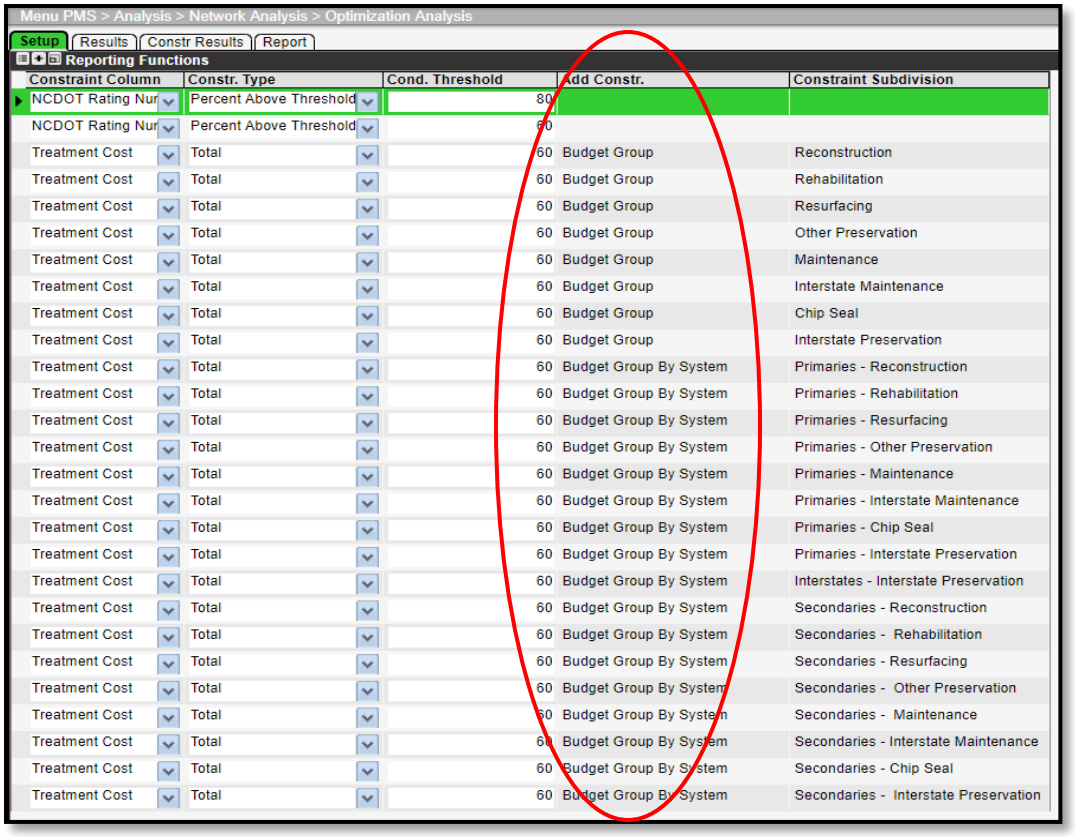
Figure 12: System Selection in PMS

Figure 13 and Figure 14 displays the constraints used for running CBA which are Treatment Cost and NCDOT Rating Number.



Is Objective	Constraint Column	Constr. Type	Constraint Limit Value	Cond. Thresho	Scenario Year Num	Add Constr.	Constraint Subdivision
☑	Treatment Cost	Total					
☐	NCDOT Rating Number	Percent Above Thresh	0.99	20		Detailed System	Interstate
☐	NCDOT Rating Number	Percent Above Thresh	0.99	20		Detailed System	NC
☐	NCDOT Rating Number	Percent Above Thresh	0.99	20		Detailed System	SR
☐	NCDOT Rating Number	Percent Above Thresh	0.99	20		Detailed System	US
☐	NCDOT Rating Number	Percent Above Thresh	0.99	40		Detailed System	Interstate
☐	NCDOT Rating Number	Percent Above Thresh	0.99	40		Detailed System	NC
☐	NCDOT Rating Number	Percent Above Thresh	0.99	40		Detailed System	SR
☐	NCDOT Rating Number	Percent Above Thresh	0.99	40		Detailed System	US
☐	NCDOT Rating Number	Percent Above Thresh	0.94	60	1	Detailed System	Interstate
☐	NCDOT Rating Number	Percent Above Thresh	0.94	60	2	Detailed System	Interstate
☐	NCDOT Rating Number	Percent Above Thresh	0.93	60	3	Detailed System	Interstate
☐	NCDOT Rating Number	Percent Above Thresh	0.93	60	4	Detailed System	Interstate
☐	NCDOT Rating Number	Percent Above Thresh	0.92	60	5	Detailed System	Interstate
☐	NCDOT Rating Number	Percent Above Thresh	0.94	60	1	Detailed System	NC
☐	NCDOT Rating Number	Percent Above Thresh	0.95	60	2	Detailed System	NC
☐	NCDOT Rating Number	Percent Above Thresh	0.95	60	3	Detailed System	NC
☐	NCDOT Rating Number	Percent Above Thresh	0.95	60	4	Detailed System	NC
☐	NCDOT Rating Number	Percent Above Thresh	0.94	60	5	Detailed System	NC
☐	NCDOT Rating Number	Percent Above Thresh	0.94	60	1	Detailed System	SR
☐	NCDOT Rating Number	Percent Above Thresh	0.93	60	2	Detailed System	SR
☐	NCDOT Rating Number	Percent Above Thresh	0.93	60	3	Detailed System	SR
☐	NCDOT Rating Number	Percent Above Thresh	0.92	60	4	Detailed System	SR
☐	NCDOT Rating Number	Percent Above Thresh	0.92	60	5	Detailed System	SR
☐	NCDOT Rating Number	Percent Above Thresh	0.94	60	1	Detailed System	US
☐	NCDOT Rating Number	Percent Above Thresh	0.94	60	2	Detailed System	US
☐	NCDOT Rating Number	Percent Above Thresh	0.93	60	3	Detailed System	US

Figure 13: Constraints Selection in PMS



Constraint Column	Constr. Type	Cond. Threshold	Add Constr.	Constraint Subdivision
NCDOT Rating Nur	Percent Above Threshold	80		
NCDOT Rating Nur	Percent Above Threshold	60		
Treatment Cost	Total	60	Budget Group	Reconstruction
Treatment Cost	Total	60	Budget Group	Rehabilitation
Treatment Cost	Total	60	Budget Group	Resurfacing
Treatment Cost	Total	60	Budget Group	Other Preservation
Treatment Cost	Total	60	Budget Group	Maintenance
Treatment Cost	Total	60	Budget Group	Interstate Maintenance
Treatment Cost	Total	60	Budget Group	Chip Seal
Treatment Cost	Total	60	Budget Group	Interstate Preservation
Treatment Cost	Total	60	Budget Group By System	Primaries - Reconstruction
Treatment Cost	Total	60	Budget Group By System	Primaries - Rehabilitation
Treatment Cost	Total	60	Budget Group By System	Primaries - Resurfacing
Treatment Cost	Total	60	Budget Group By System	Primaries - Other Preservation
Treatment Cost	Total	60	Budget Group By System	Primaries - Maintenance
Treatment Cost	Total	60	Budget Group By System	Primaries - Interstate Maintenance
Treatment Cost	Total	60	Budget Group By System	Primaries - Chip Seal
Treatment Cost	Total	60	Budget Group By System	Primaries - Interstate Preservation
Treatment Cost	Total	60	Budget Group By System	Interstates - Interstate Preservation
Treatment Cost	Total	60	Budget Group By System	Secondaries - Reconstruction
Treatment Cost	Total	60	Budget Group By System	Secondaries - Rehabilitation
Treatment Cost	Total	60	Budget Group By System	Secondaries - Resurfacing
Treatment Cost	Total	60	Budget Group By System	Secondaries - Other Preservation
Treatment Cost	Total	60	Budget Group By System	Secondaries - Maintenance
Treatment Cost	Total	60	Budget Group By System	Secondaries - Interstate Maintenance
Treatment Cost	Total	60	Budget Group By System	Secondaries - Chip Seal
Treatment Cost	Total	60	Budget Group By System	Secondaries - Interstate Preservation

Figure 14: Reporting Functions Selection in PMS

3.2 Ideal Weight Factors Set

After the CBA was performed for the 33 weight factors set, a linear regression was conducted to find the ideal weight factor set. All the constraint reports of the 33 weight factors set were studied. Resulting values of treatment cost for all 33 weight factors were obtained from the constraint reports individually and were added to obtain a total treatment cost for each weight factor set.

An example for a constraint report is represented in Figure 15 below.

Constraint Column	Constr. Type	Scenario Year Number	Resulting Value	Cond. Threshold	Total Constraint Weight	Constraint Subdivision
NCDOT Rating Number	Percent Above Threshold	1	.9	80.00	186220.65	
NCDOT Rating Number	Percent Above Threshold	1	.95	60.00	186220.65	
NCDOT Rating Number	Percent Above Threshold	2	.87	80.00	186220.65	
NCDOT Rating Number	Percent Above Threshold	2	.95	60.00	186220.65	
NCDOT Rating Number	Percent Above Threshold	3	.87	80.00	186220.65	
NCDOT Rating Number	Percent Above Threshold	3	.95	60.00	186220.65	
NCDOT Rating Number	Percent Above Threshold	4	.86	80.00	186220.65	
NCDOT Rating Number	Percent Above Threshold	4	.94	60.00	186220.65	
NCDOT Rating Number	Percent Above Threshold	5	.85	80.00	186220.65	
NCDOT Rating Number	Percent Above Threshold	5	.93	60.00	186220.65	
Treatment Cost	Total	1	3894894[illegible]		26759.01	Chip Seal
Treatment Cost	Total	2	24350536.		2078.27	Chip Seal
Treatment Cost	Total	3	52153037.		3944.44	Chip Seal
Treatment Cost	Total	4	91087069.		6111.66	Chip Seal
Treatment Cost	Total	5	56878216.		4013.57	Chip Seal
Treatment Cost	Total	1			0.00	Interstate Maintenance
Treatment Cost	Total	2			0.00	Interstate Maintenance
Treatment Cost	Total	3			0.00	Interstate Maintenance
Treatment Cost	Total	4	7066353.		57.04	Interstate Maintenance
Treatment Cost	Total	5	52579726.		419.31	Interstate Maintenance
Treatment Cost	Total	1			0.00	Interstate Preservation
Treatment Cost	Total	2			0.00	Interstate Preservation
Treatment Cost	Total	3			0.00	Interstate Preservation
Treatment Cost	Total	4			0.00	Interstate Preservation
Treatment Cost	Total	5			0.00	Interstate Preservation
Treatment Cost	Total	1			0.00	Maintenance
Treatment Cost	Total	2			0.00	Maintenance
Treatment Cost	Total	3			0.00	Maintenance
Treatment Cost	Total	4			0.00	Maintenance
Treatment Cost	Total	5			0.00	Maintenance
Treatment Cost	Total	1	102230512.		9079.52	Other Preservation
Treatment Cost	Total	2	50940775.		5062.12	Other Preservation
Treatment Cost	Total	3	73599333.		7408.12	Other Preservation
Treatment Cost	Total	4	73077535.		8021.07	Other Preservation
Treatment Cost	Total	5	61024832.		9244.43	Other Preservation
Treatment Cost	Total	1	11877.		0.13	Reconstruction
Treatment Cost	Total	2			0.00	Reconstruction
Treatment Cost	Total	3	1225456.		4.44	Reconstruction
Treatment Cost	Total	4	356306.		1.78	Reconstruction
Treatment Cost	Total	5	89296.		0.64	Reconstruction
Treatment Cost	Total	1	179157095.		1964.03	Rehabilitation
Treatment Cost	Total	2	143955699.		1455.05	Rehabilitation
Treatment Cost	Total	3	212878797.		2105.21	Rehabilitation
Treatment Cost	Total	4	162348762.		1466.09	Rehabilitation
Treatment Cost	Total	5	177333275.		1440.18	Rehabilitation
Treatment Cost	Total	1	1095504029.		24138.84	Resurfacing
Treatment Cost	Total	2	30830365.		494.12	Resurfacing
Treatment Cost	Total	3	81614056.		1610.64	Resurfacing
Treatment Cost	Total	4	199125350.		4439.37	Resurfacing
Treatment Cost	Total	5	134387217.		2741.16	Resurfacing
Treatment Cost	Total	1			0.00	Interstates - Chip Seal

Figure 15: Constraint Report

Table 3 represents the treatment cost for all the 33 weight factors:

Table 3: Treatment Cost of 33 Weight Factors

Interstate	US	NC	SR	Treatment Cost ($\times 10^9$)
2	1.7	1.3	1	7.30E
1.3	1.2	1.1	1	7.31E
3	2.7	2.3	1	7.31E
1.8	1.4	1.2	1	7.29E
2.9	1.5	1.3	1	7.22E
2.4	2.1	1.8	1	7.30E
2.7	2.1	1.4	1	7.29E
2.1	1.8	1.1	1	6.38E
2.2	2	1.8	1	6.41E
2.7	2.3	2	1	6.40E
2.9	1.4	1.3	1	6.37E
2.6	2.4	1.6	1	6.41E
2	1.5	1.2	1	6.39E
2.9	1.7	1.1	1	6.37E
1.9	1.4	1.3	1	6.71E
2.9	2.5	1.7	1	6.61E
1.8	1.7	1.5	1	6.65E
2.9	2.6	2.1	1	6.65E
2.6	1.5	1.3	1	6.66E

2.8	2.5	1.3	1	6.71E
3	2.6	1.6	1	6.70E
2.8	2.4	1.4	1	6.70E
1.9	1.8	1.1	1	6.70E
2.5	2.2	1.3	1	6.70E
2.2	2.1	1.3	1	6.67E
2.8	1.7	1.3	1	6.56E
2.4	2	1.3	1	6.60E
2.3	2.1	1.9	1	6.61E
3	2.6	1.2	1	6.60E
3	1.9	1.7	1	6.57E
2.4	1.8	1.3	1	6.58E
2.2	1.8	1.2	1	6.59E
1.7	1.4	1.3	1	6.59E

A linear regression was performed for the values represented in Table 3. A graph was developed representing Interstates, US and NC regression results. It was plotted between weight factors and treatment cost. Figure 16 shows the graph obtained from the linear regression

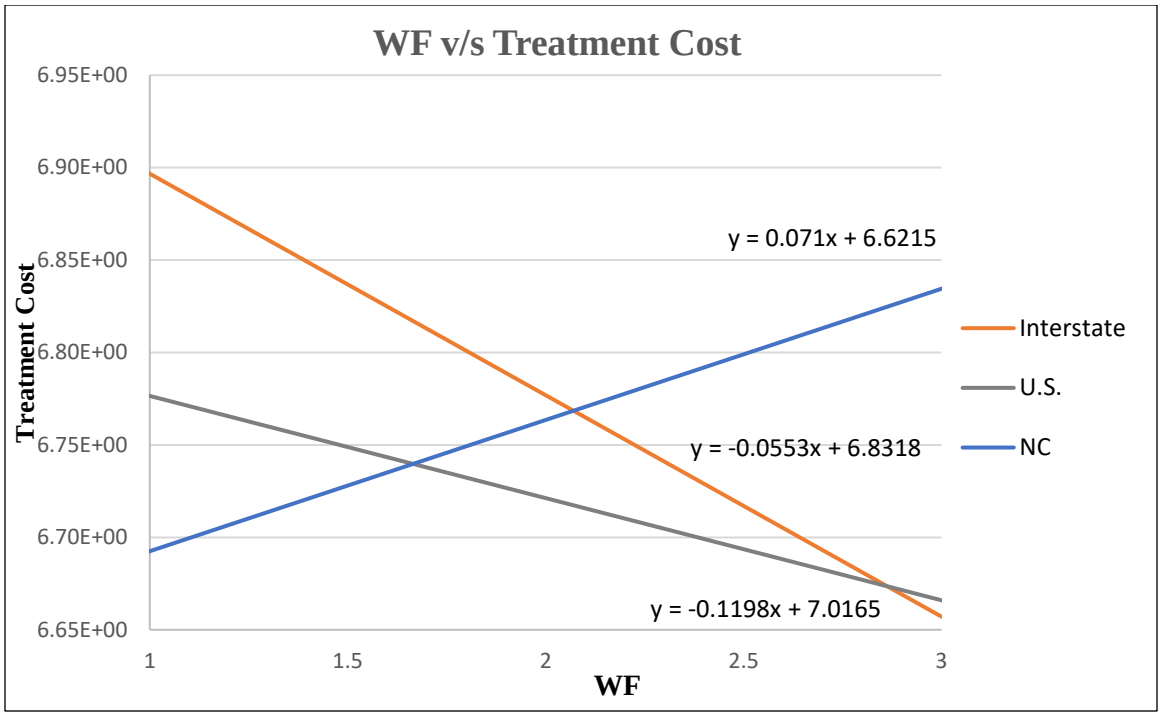


Figure 16: Linear Regression Graph

Linear equations for Interstates, US and NC were obtained by doing the linear regression. Table 4 represents the linear equations and R^2 values for the same:

Table 4: Linear Regression Equations

System	Linear Equation	R^2
Interstates	y = -0.1198x + 7.0165	0.0307
US	y = -0.0553x + 6.8318	0.0056
NC	y = 0.071x + 6.6215	0.0049

The R-squared values obtained were very less since the linear regression was used instead of polynomial regression. By using polynomial regression, obtaining points of intersections in the graphs was difficult. Therefore, the linear regression was applied

resulting in low R-squared values. Two horizontal lines were drawn for the Figure 17 to determine the possible set of weight factors. Figure 17 shows the two lines drawn for finding the new best possible values of weight factors. By moving those lines vertically an intersection point was found which satisfied the weight factors value condition, which is that the weight factor (WF) for 4 roadway systems are in descending order, as follows:

WF(Interstate) > WF (US) > WF (NC) > WF (SR)

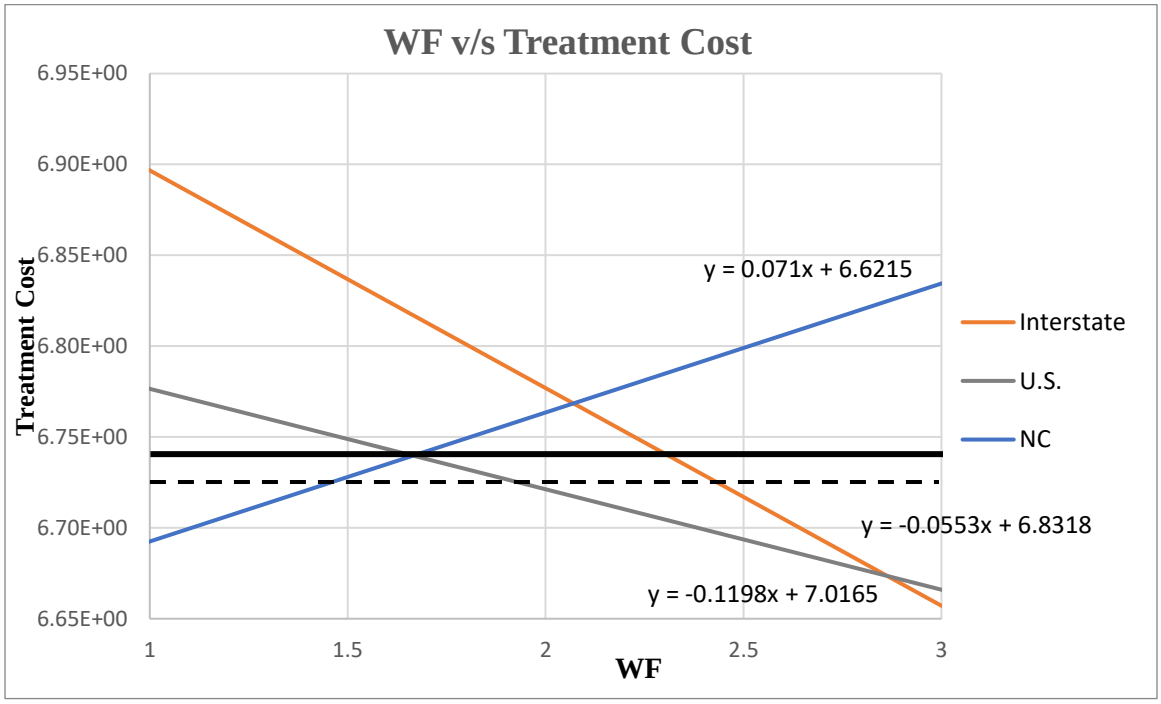


Figure 17: New Weight Factors Selection

Since the intersection of lines having the least treatment cost was considered, the linear equations for NC and US were selected. After solving those equations simultaneously, the value for ‘x’ and ‘y’ were obtained as 1.665 and 6.739 respectively as follows:

$$y = 0.071x + 6.6215$$

$$y = -0.0553x + 6.8318$$

$$x = 1.665$$

$$y = 6.739$$

After drawing those lines, it was assumed that the value of NC weight factors is 1.5 because SR weight factor has the value of 1.0. Hence, the value of 1.5 was substituted in the NC linear regression equation as 'x' value and obtained the value for 'y' as 6.729.

$$y = 0.071x + 6.6215$$

$$y = 0.071 \text{ x } 1.5 + 6.6215$$

$$y = 6.729$$

From the two values of 'y' obtained above, the remaining values for 'y' were divided at an equal interval between 6.739 and 6.729. By substituting the 'y' values in each linear equation, the new weight factor values were obtained and were considered as the new weight factors. Five new weight factors set were obtained. For Interstates, the x value was represented as x1, the US as x2, NC as x3 and SR as x4. Table 5 represents the new values of 'y' which were used to set new values for the new weight factors.

Table 5: New Weight Factors

	x1	x2	x3	x4
y	Interstate	U.S.	NC	SR
6.737	2.3	1.7	1.6	1
6.735	2.3	1.8	1.6	1
6.733	2.4	1.8	1.6	1
6.731	2.4	1.8	1.5	1
6.729	2.4	1.9	1.5	1

CBA was conducted once again for the new 5 weight factors set. All the constraint reports were studied, and the resulting values for the treatment cost constraint were added for the treatment cost. This time, the ideal weight factor set are the one that yields the least treatment cost. Table 6 shows the treatment cost value for each of the 5 weight factors set.

Table 6: Ideal Weight Factors Set

Interstate	U.S.	NC	SR	Treatment Cost
2.3	**1.7**	**1.6**	**1.0**	**$6,577,321,999**
2.4	1.8	1.5	1.0	$6,577,846,429
2.4	1.8	1.6	1.0	$6,580,960,537
2.3	1.8	1.6	1.0	$6,582,490,075
2.4	1.9	1.5	1.0	$6,584,023,731

The weight factor set (2.3, 1.7, 1.6, 1.0) was selected as an ideal weight factor set because of its the least treatment cost.

3.3 Fund Allocation for 14 Divisions

Using the final set of weight factors, another round of CBA was performed again. This time it was performed for all the 14 Divisions individually. By doing this, the treatment cost for each Division according to the three fund types was determined. The results for each Division were studied and the fund allocation was performed according to each fund type.

3.3.1 Fund Allocation Example

An example calculation of the treatment cost and its allocation according to funds types is presented in this section. Information used in this example is obtained from the actual results for Division 6 from the NCDOT's PMS.

After sorting the data according to each system, the total cost was obtained. Table 7 shows the total cost associated with each system for Division 8:

Table 7: Fund Allocation Example

System	Total Cost	Percentage
Interstates	$ 18,087,813.00	8.04
U.S.	$ 25,577,807.00	11.37
NC	$ 50,178,179.00	22.31
SR	$ 131,035,999.00	58.27
Total	$ 224,879,798.00	100.00

Fund I include the Interstate maintenance, preservation and resurfacing. Hence, the total cost accounting for them was added and the percentage associated with it was calculated. The total cost for the Fund I calculated for Division 6 is presented in Table 8:

Table 8: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 18,087,813.00
Total	$ 18,087,813.00

The total cost for Fund II which is calculated for Division 6 is presented in Table 9.

Table 9: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage (%)
U.S.	$ 20,509,957.00	19.89
NC	$ 36,440,291.00	35.33
SR	$ 46,185,034.00	44.78
Total	$ 103,135,282.00	100.00

The total cost for Fund III which is calculated for Division 6 is presented in Table 10.

Table 10: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage
U.S.	$ 5,067,850.00	4.89
NC	$ 13,737,888.00	13.25
SR	$ 84,850,965.00	81.86
Total	$ 103,656,703.00	100.00

After calculating the treatment costs for all the three fund types, the overall percentage allocation for each fund type was calculated. Table 11 represents the percentages of funds allocated to each fund type.

Table 11: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	8.04
Fund II	45.86
Fund III	46.10

Therefore, for Division 6 it can be concluded that Fund I have the least treatment cost which is contributing to 8.04% of the total cost. Similarly, for Fund II it is 45.86% and Fund III has the highest share of 46.10% of the total cost.

3.4 Fund Allocation according to regional classification

North Carolina comprises of three main regions namely:

- Mountains
- Piedmont
- Coastal Plain

Figure 18 shows the North Carolina map representing the three regions (ncforestservices, 2017).

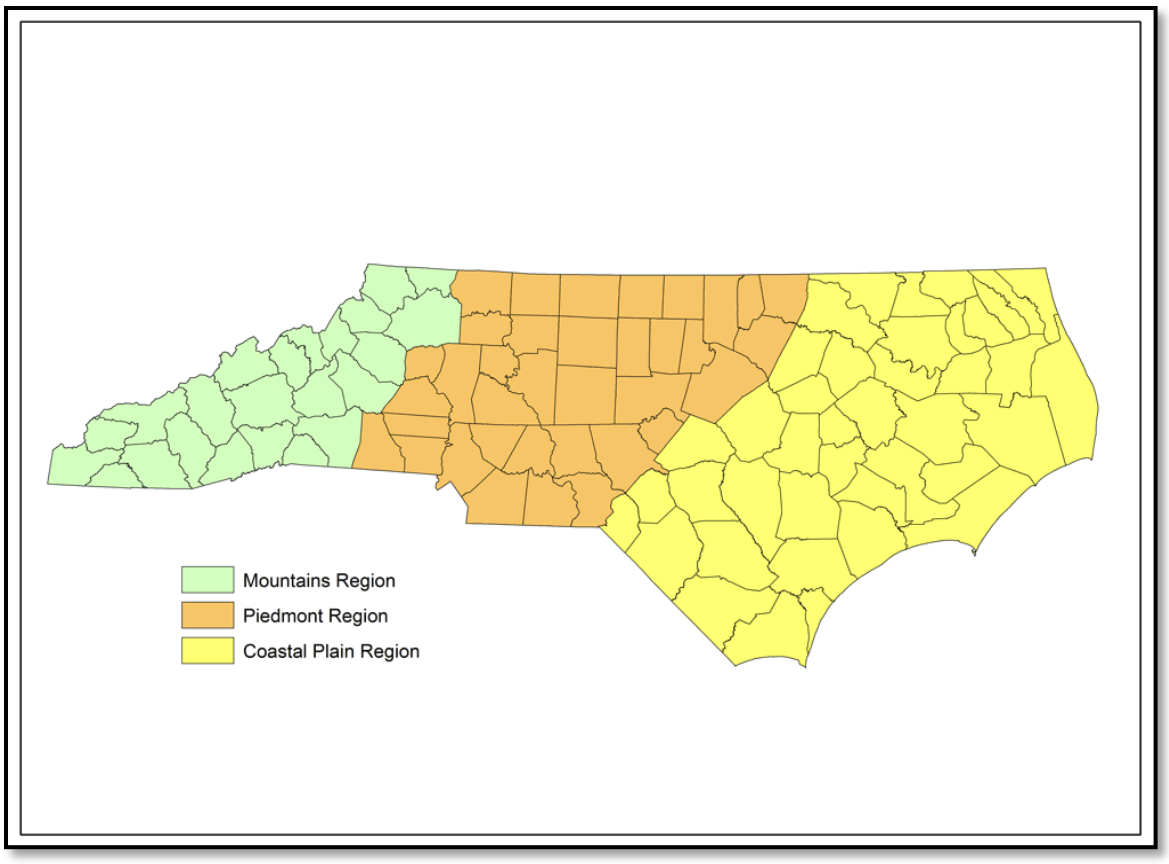


Figure 18: North Carolina's Regional Classification

After comparing the North Carolina regional map with the NCDOT Division map, the Divisions under each of the three regions were determined. Figure 19 shows the NCDOT's Divisions map which was used for finding the Divisions underlying each region (ncforestservices, 2017).

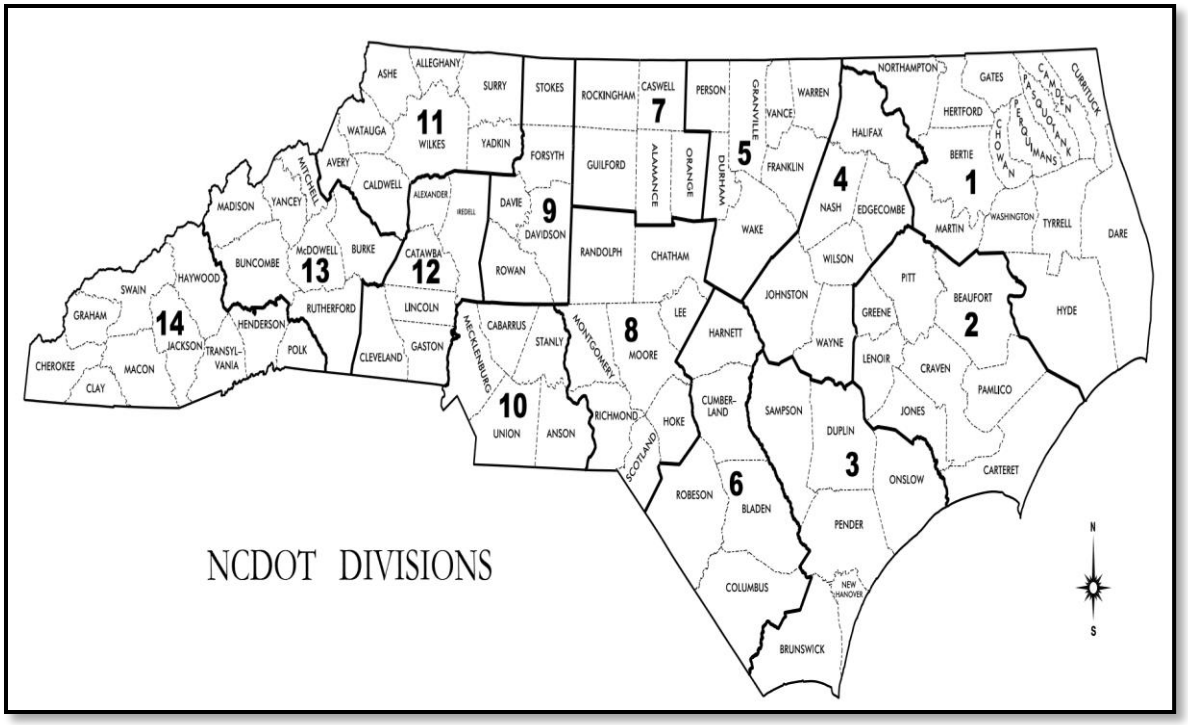


Figure 19: NCDOT's Divisions

Table 12 shows the Divisions within each of the three regions:

Table 12: Divisions under the regional classification

Regions	Division
Mountains	11, 12, 14
Piedmont	5, 7, 8, 9, 10, 12
Coastal Plains	1, 2, 3, 4, 6

The main purpose of dividing the Divisions according to the regions was to find the project cost for each treatment according to its Division depending upon the type of regions. It will give an idea about the total amount of cost required for each treatment type depending upon the regions.

Table 13: Treatments under each fund type (NCDOT: Highway Sections & Units, 2018)

Fund Type	Treatments
I	• Interstate Maintenance • Interstate Preservation • Interstate Resurfacing • Other Preservation
II	• Overlay • Mill-Fill
III	• Single Seal • Double Seal • Triple Seal • Fog Seal • Slurry Seal • Seal Crack • Wheel Patching • Full Depth Patching

Figures 20 through 22 represent the cost for each treatment type for the mountain region according to each fund type.

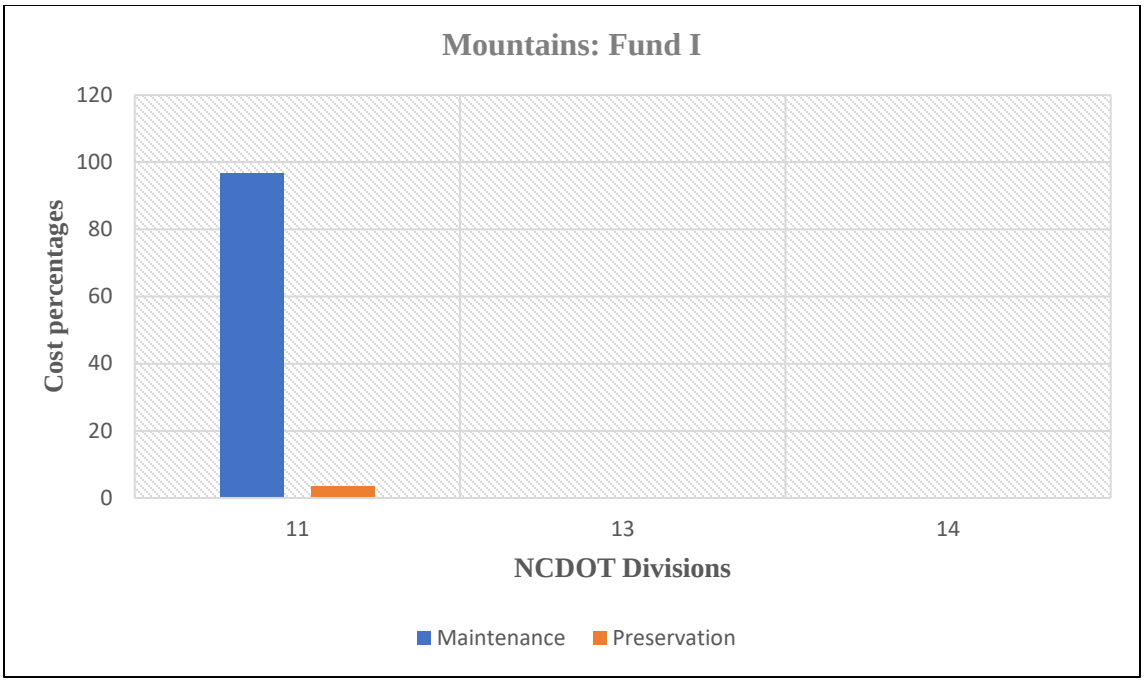


Figure 20: Treatment cost for Mountains: Fund I

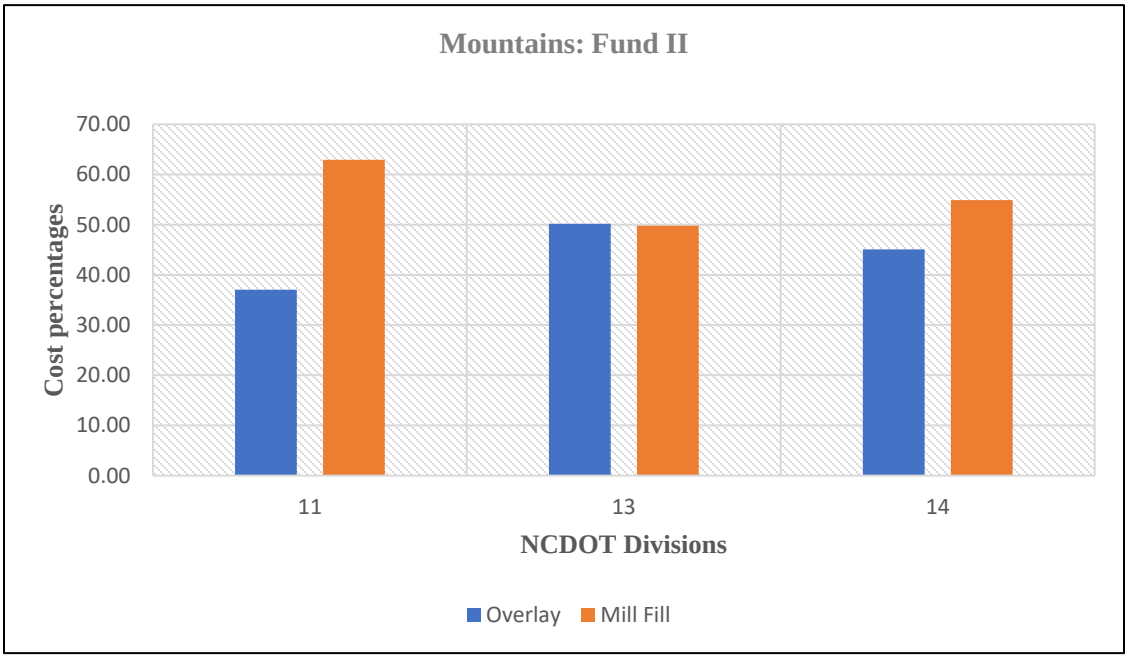


Figure 21: Treatment cost for Mountains: Fund II

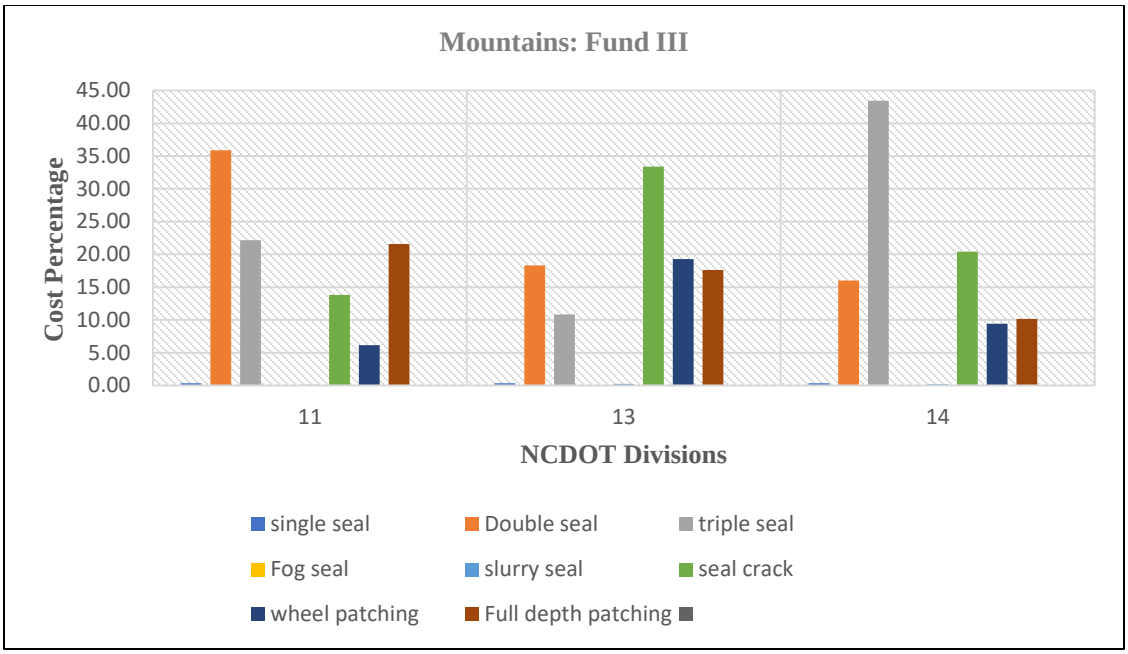


Figure 22; Treatment cost for Mountains: Fund III

Figures 23 through 25 represent the cost for each treatment type for the Piedmont region according to each fund type.

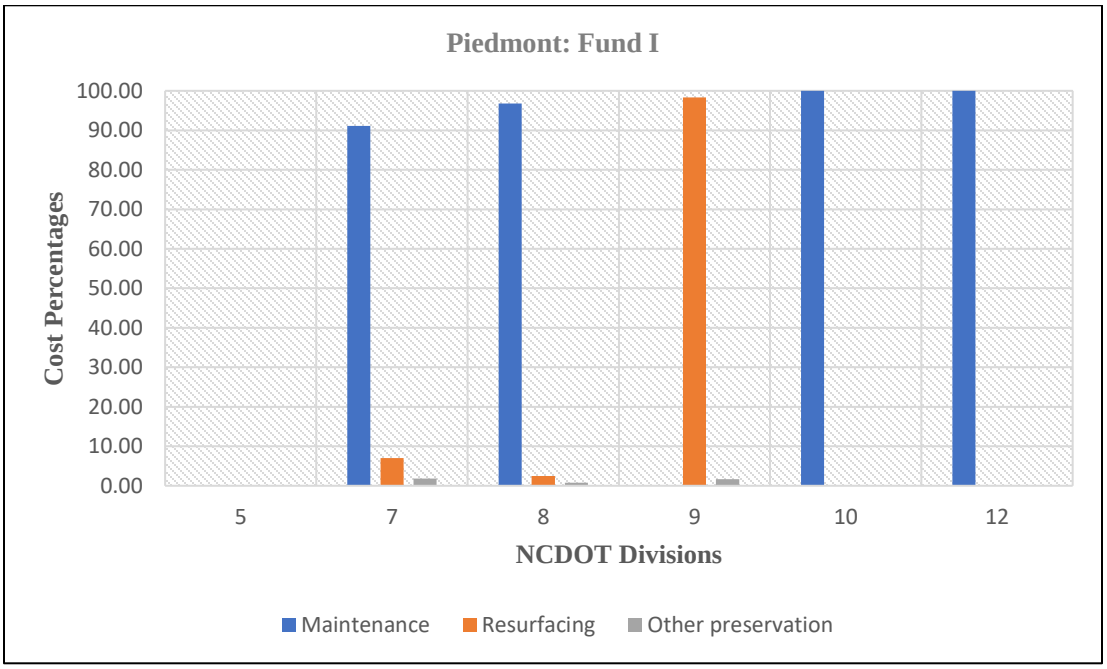


Figure 23: Treatment cost for Piedmont: Fund I

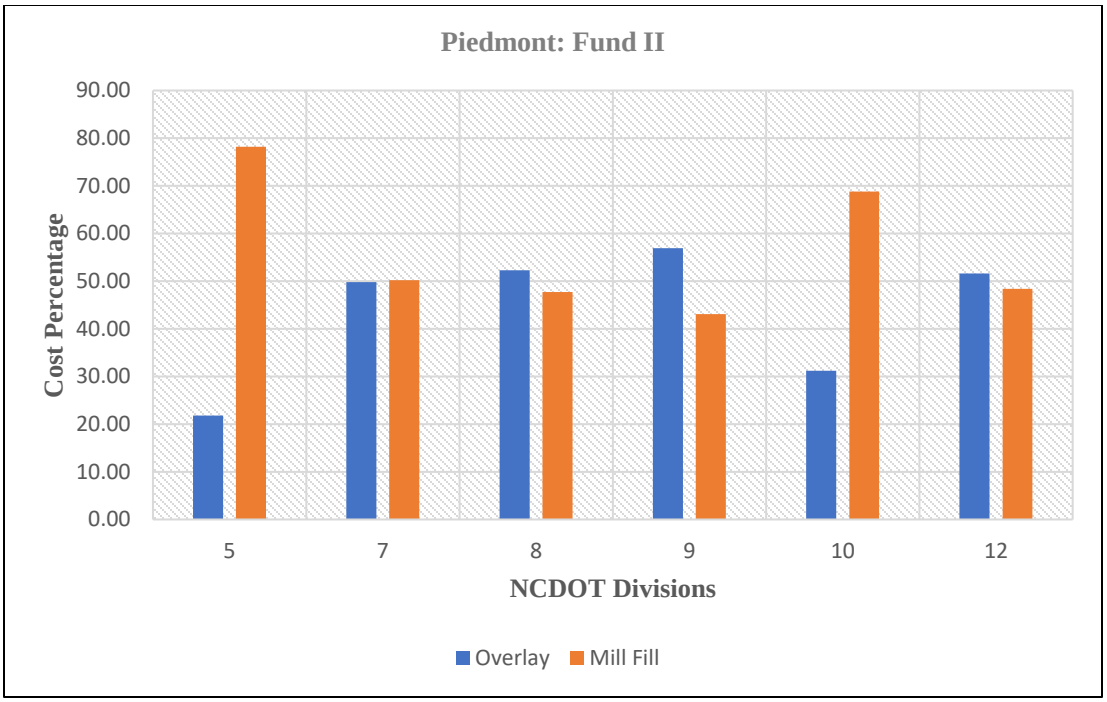


Figure 24: Treatment cost for Piedmont: Fund II

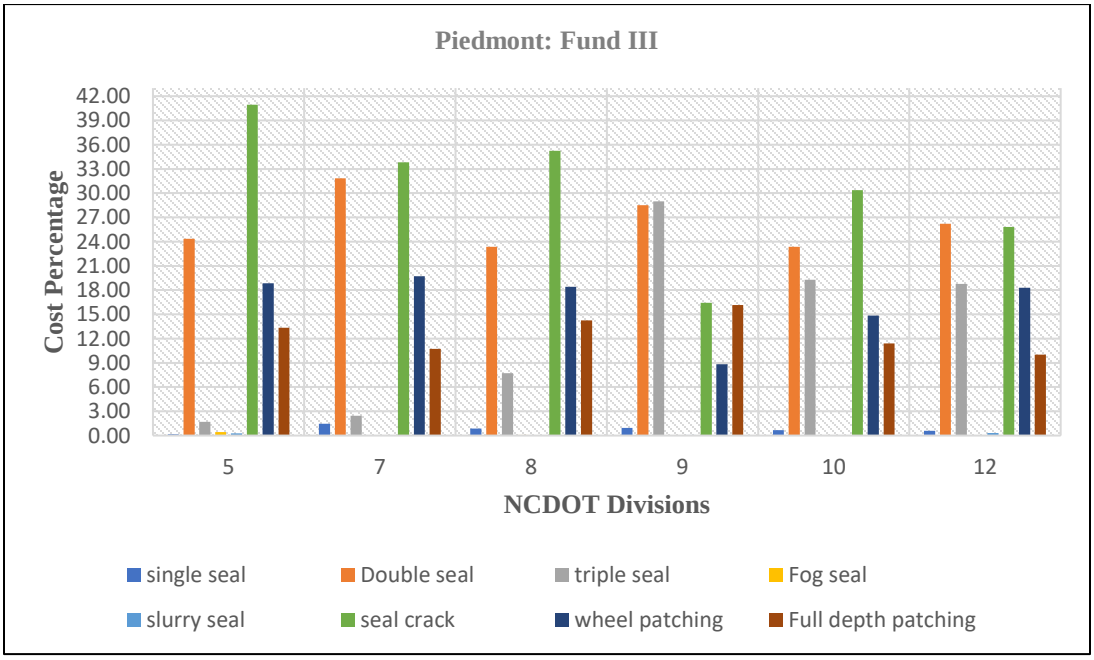


Figure 25: Treatment cost for Piedmont: Fund III

Figures 26 through 28 represent the cost for each treatment type for the Coastal Plains region according to each fund type.

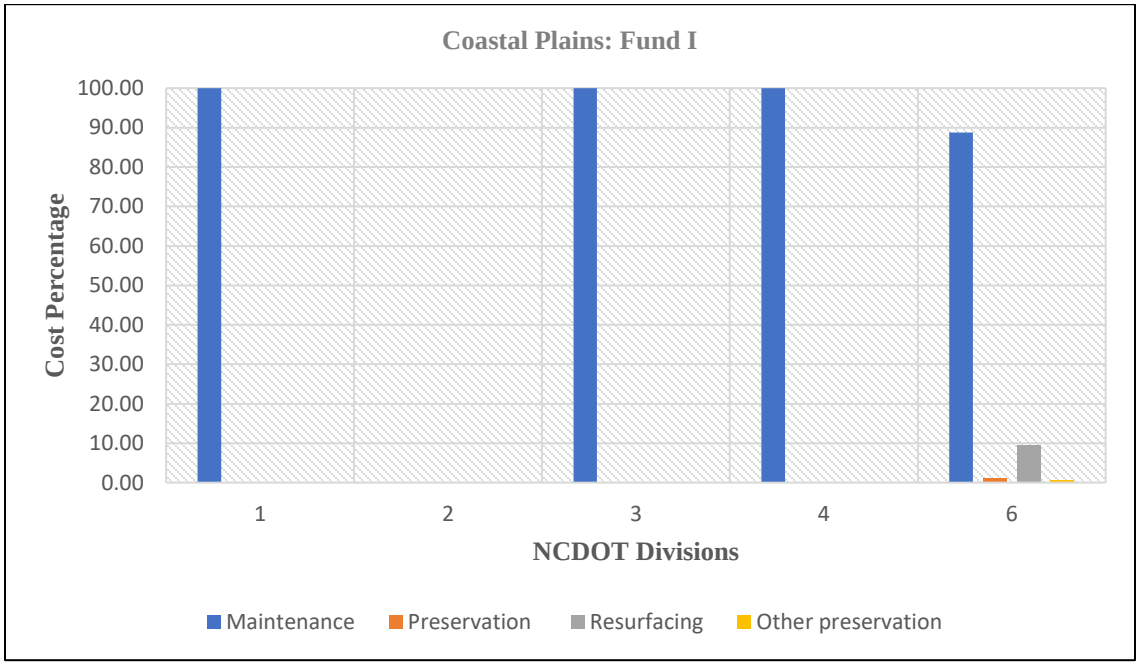


Figure 26: Treatment cost for Coastal Plains: Fund I

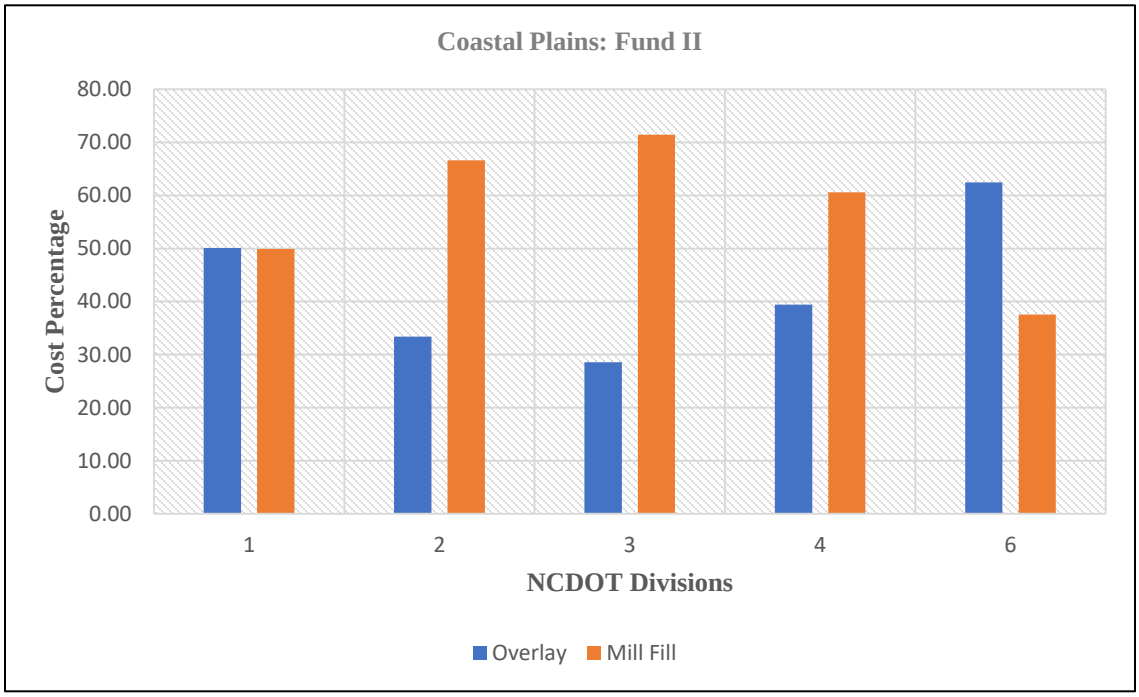


Figure 27: Treatment cost for Coastal Plains: Fund II

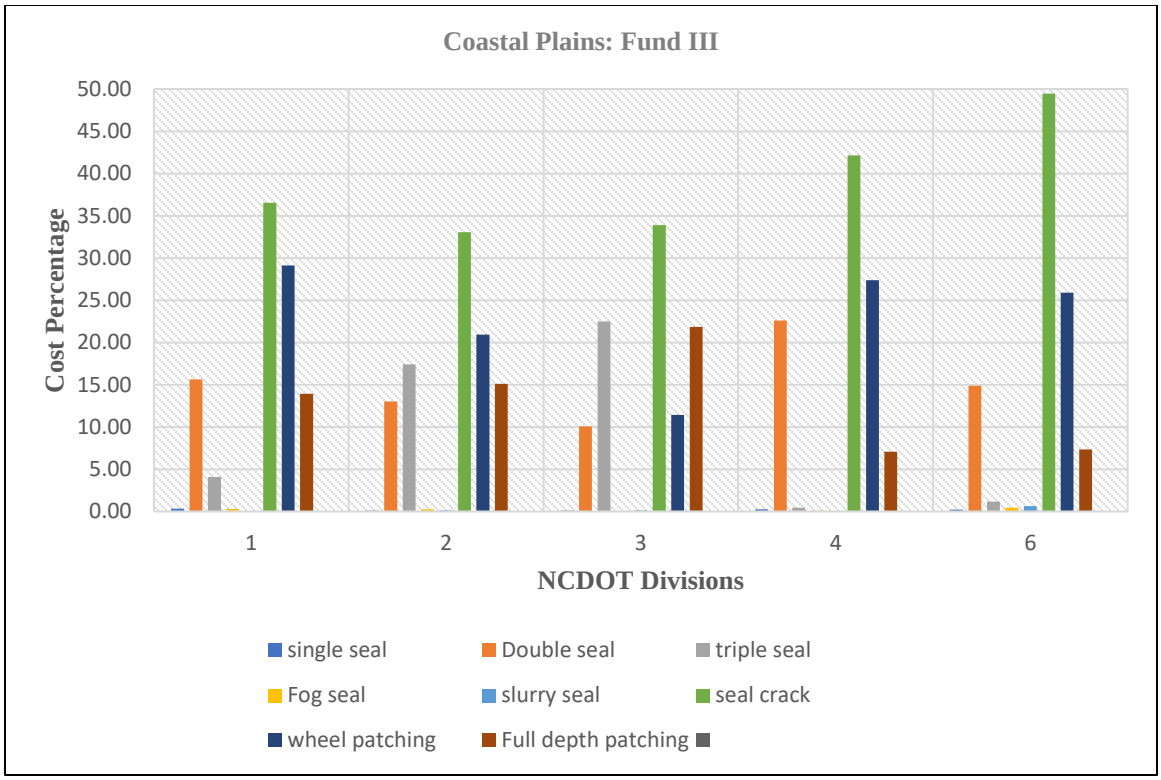


Figure 28: Treatment cost for Coastal Plains: Fund III

CHAPTER 4: DISCUSSION OF RESULTS

This chapter discusses the findings of this research.

The weight factor set which was selected based on the least treatment cost was 2.3, 1.7, 1.6 and 1.0. By using this weight factor set, it can help the NCDOT to obtain more accurate results in terms of treatment costs which will help in minimizing the total cost and maximizing the benefits by covering more roads for treatment.

After running the CBA again for the 14 Divisions individually using the ideal weight factors set, the distribution of funds according to the Divisions and regions were determined.

4.1 Analysis of Result

The researchers developed various graphs to understand and show the funds distribution amongst the Divisions. Figure 29 shows the graph which was developed between Divisions and percentages according to each fund types.

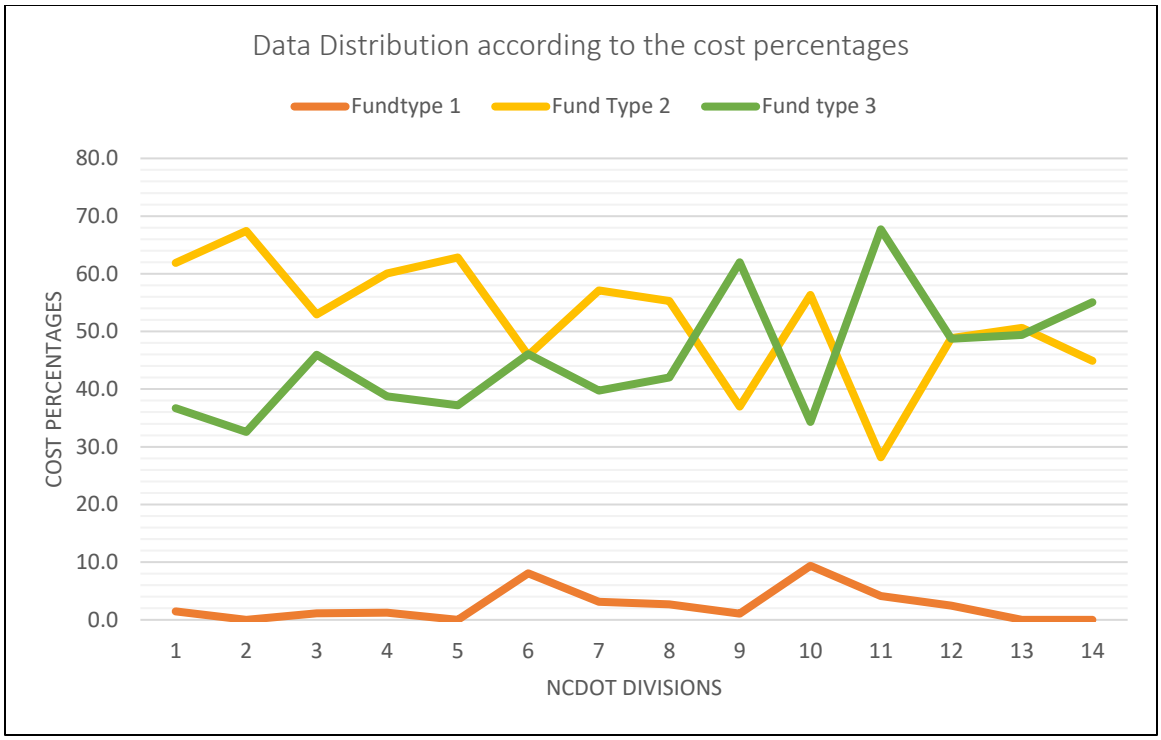


Figure 29: Data distribution of fund types

From Figure 29 it can be concluded that Divisions 6, 7, 8, 10, 11 and 12 have the significant amount of Fund I as compared to other Divisions. Fund II is evenly distributed in Divisions 2, 5, 7, 8, 10, 12 and 13. Fund III has more use in Divisions 1, 3, 6, 9, 10, 11 and 14.

4.2 Result Findings

This research presents a framework that can be used for allocating funds to each Division and regions according to the treatment types by using the ideal set of weight factors for the NCDOT'S PMS. Various analyses were performed for all the 14 Divisions using 33 weight factors set for determining the ideal weight factors set. Using the ideal weight factors set, a CBA was conducted again for finding the treatment costs for each Division according to the three fund types. Also, the treatment cost according to the three

regions of North Carolina was determined. using this framework, the treatment cost for any Division and for any treatment type can be obtained

4.3 Case Study

A case study is provided in this section to illustrate how the findings of this study can be applied to real world scenarios. In this study, the above methodology was applied to an assumed budget of $50,000,000. The sample fund allocation is for the pavements according to the Fund I, Fund II and Fund III and regional classification such as mountains, Piedmont, and coastal plains. All the four systems were taken into consideration. Constraints such as NCDOT Rating Number and treatment cost are applied. The application of the methodology of the funding allocation is described.

Usually, the NCDOT allocate the funds according to their need for a Division or for primaries and secondaries roadway. In this study, the funds are allocated according to each type and regional classification. According to the arithmetic mean of the funds allocated to each type, approximately 2.5% of the total funds available are assigned to Fund I, 52.1% to Fund II and 45.45 to Fund III. Figure 30 shows the Divisions of the assumed budget of $50,000,000 for each fund type.

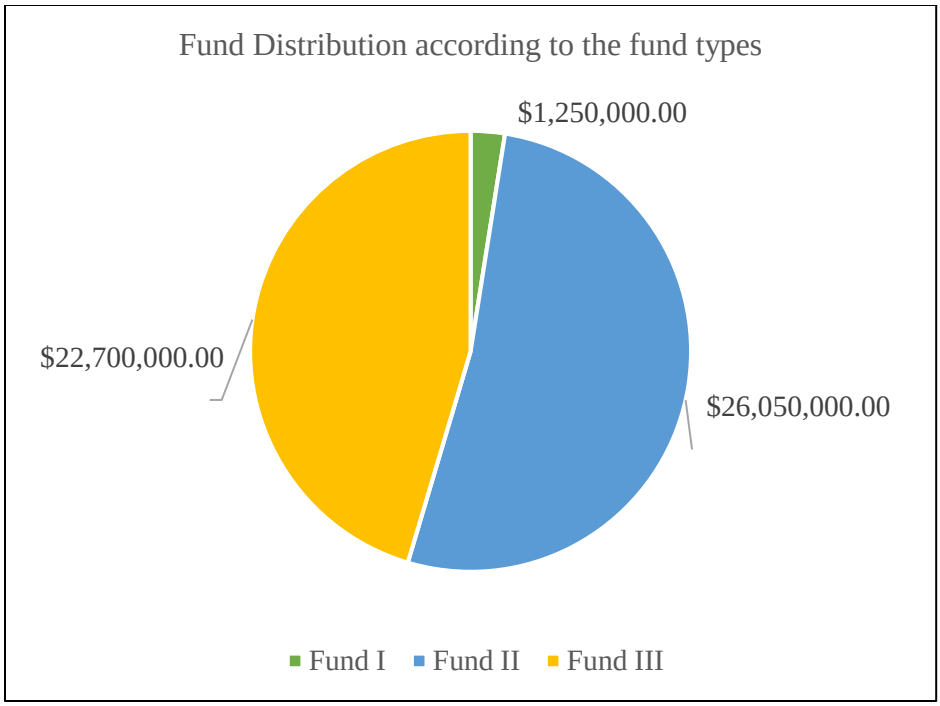


Figure 30: Fund distribution

From the Figure 30, it can be said that more amount of funds was allocated for Fund II, then for Fund III and least is for the Fund I.

When the budget was assigned according to the regional classification, the following pie charts from Figure 31 through 33 were developed showing the approximate percentages of funds that should be allocated to mountains, Piedmont and coastal regions.

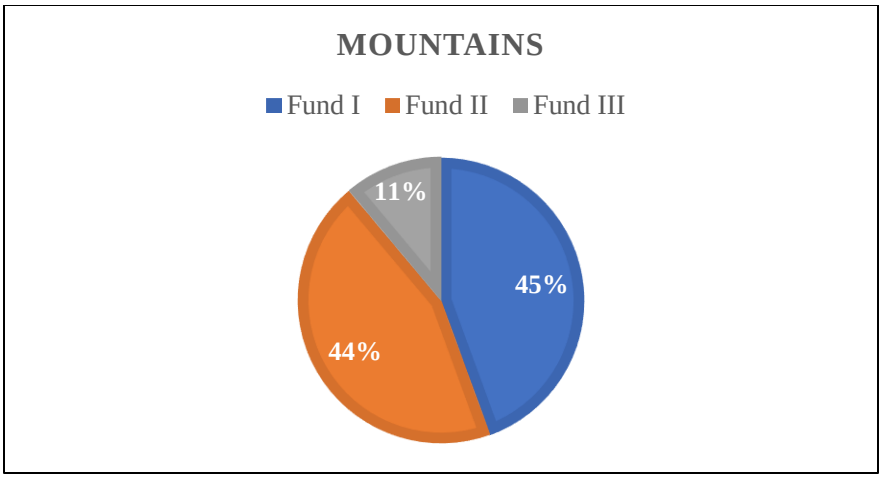


Figure 31: Fund distribution for Mountains

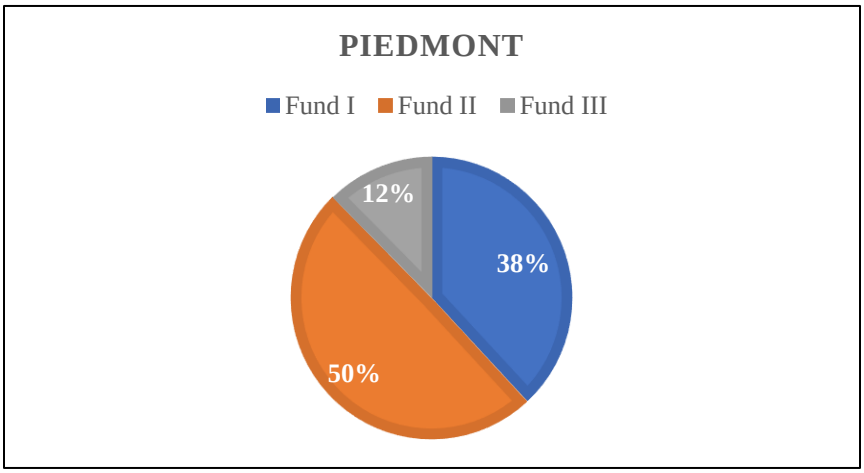


Figure 32: Fund distribution for Piedmont

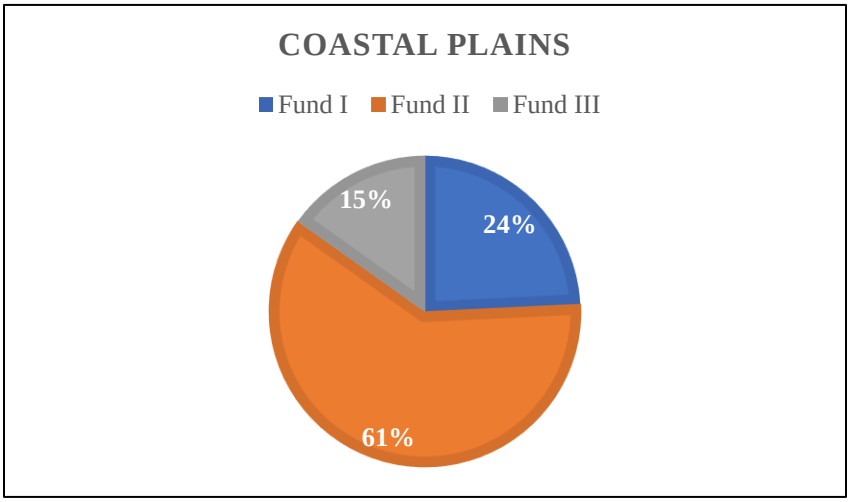


Figure 33: Fund distribution for Coastal Plains

From Figures 31, 32 and 33, it was observed that more budget was been allocated for Fund II i.e., for contract resurfacing, second highest for Fund I i.e. for Interstates maintenance and the least for the Fund III which is pavement preservation.

By using this framework for fund allocation, any budget can be allocated to a specific region, Division or a Division within a region. Also, this framework can help Engineers to have an idea about the amount of fund needed or if the budget is available, then how to allocate that budget.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The goal of this study is to obtain an ideal weight factors set and use them for allocating the maintenance budget by running CBA for the roadway network in North Carolina. The following conclusions were drawn:

- The ideal weight factors for Interstates, US, NC and SR are 2.3, 1.7, 1.6 and 1.0 respectively.
- For a given budget, the overall percentages of Fund I, II and III are 2.5%, 52.1% and 45.4% respectively.
- For a given budget, the overall percentages of Fund I, II and III in each region are:
    - Mountains: 45% for Fund I, 44% for Fund II and 11% for Fund III.
    - Piedmont: 38% for Fund I, 50% for Fund II and 12% for Fund III.
    - Coastal regions: 24% for Fund I, 61% for Fund II and 15% for Fund III.
- The framework developed in this study can be easily adopted by other state DOTs for them to make informed investment decisions.

5.2 Significance of Research

The significance of this research is achieving optimal maintenance of roadways within budget. This means that the right roadway can be treated at right time. The method of determining ideal weight factors set in this research can be used by state DOTs to minimize the treatment cost and maximize benefits. The framework developed in this study can be used for one division or many divisions together in the PMS and treatment costs for any roadway of any Division can be calculated. Also, the same framework can benefit other DOT's as well for proper allocation of funds.

5.3 Future Recommendations

The following recommendations are made for future research projects:

- Firstly, it is recommended to find the ideal set of weight factors by using the benefit as a constraint instead of treatment cost to determine which weight factors set has the maximum benefit. By using benefit as the constraint, the fund allocation for the Divisions will be different. The results obtained can be compared with the results obtained by using treatment cost as the constraint, the differences can help researchers and Engineers determine which constraint is more appropriate.
- Secondly, CBA can be performed for the divisions within the geographical regions using the PMS. It can be performed for the Mountains, Piedmont and the Coastal Plains regions individually. These detailed results can assist DOT engineers in making more accurate maintenance decisions.
- Lastly, an assumed treatment budget can be used as a constraint when running CBA for budget allocation purposes. The results can provide an imperative perspective to engineers when the annual budget is known.

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APPENDIX A: BUDGET ALLOCATION BY FUND TYPES FOR DIVISIONS

Division 1

Table A-1: Total Treatment Cost for Division 1

System	Total Cost	Percentage (%)
Interstates	$ 2,677,305.00	1.5
U.S.	$ 36,015,825.00	19.7
NC	$ 31,918,880.00	17.5
SR	$ 112,031,550.00	61.3
Total	$ 182,643,560.00	100.0

Table A-2: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 2,677,305.00
Total	$ 2,677,305.00

Table A-3: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 27,874,976.00	24.7
NC	$ 25,308,918.00	22.4
SR	$ 59,789,831.00	52.9
Total	$ 112,973,725.00	100.0

Table A-4: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 8,140,849.00	12.2
NC	$ 6,609,962.00	9.9
SR	$ 52,241,719.00	78.0
Total	$ 66,992,530.00	100.0

Table A-5: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	1.5
Fund II	61.9
Fund III	36.7

Division 2

Table A-6: Total Treatment Cost for Division 2

System	Total Cost	Percentage (%)
U.S.	$ 59,635,641.00	24.6
NC	$ 32,331,893.00	13.4
SR	$ 150,181,458.00	62.0
Total	$ 242,148,992.00	100.0

Table A-7: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 55,283,613.00	33.9
NC	$ 27,418,713.00	16.8
SR	$ 80,555,163.00	49.3
Total	$ 163,257,489.00	100.0

Table A-8: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 4,352,028.00	5.5
NC	$ 4,913,180.00	6.2
SR	$ 69,626,295.00	88.3
Total	$ 78,891,503.00	100.0

Table A-9: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	0
Fund II	67.4
Fund III	32.6

Division 3

Table A-10: Total Treatment Cost for Division 3

System	Total Cost	Percentage (%)
Interstates	$ 2,335,213.00	1.1
U.S.	$ 56,535,624.00	27.0
NC	$ 32,835,167.00	15.7
SR	$ 117,621,390.00	56.2
Total	$ 209,327,394.00	100.0

Table A-11: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 2,335,213.00
Total	$ 2,335,213.00

Table A-12: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 49,161,958.00	44.4
NC	$ 22,107,009.00	19.9
SR	$ 39,569,953.00	35.7
Total	$ 110,838,920.00	100.0

Table A-13: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 7,373,666.00	7.7
NC	$ 10,728,158.00	11.2
SR	$ 78,051,437.00	81.2
Total	$ 96,153,261.00	100.0

Table A-14: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	1.1
Fund II	53.0
Fund III	45.9

Division 4

Table A-15: Total Treatment Cost for Division 4

System	Total Cost	Percentage (%)
Interstates	$ 3,540,117.00	1.2
U.S.	$ 68,893,878.00	23.7
NC	$ 43,713,103.00	15.0

SR	$ 174,805,887.00	60.1
Total	$ 290,952,985.00	100.0

Table A-16: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 3,540,117.00
Total	$ 3,540,117.00

Table A-17: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 61,456,541.00	35.2
NC	$ 31,139,657.00	17.8
SR	$ 82,151,758.00	47.0
Total	$ 174,747,956.00	100.0

Table A-18: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 7,437,337.00	6.6
NC	$ 12,573,446.00	11.2
SR	$ 92,654,129.00	82.2
Total	$ 112,664,912.00	100.0

Table A-19: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	1.2
Fund II	60.1
Fund III	38.7

Division 5

Table A-20: Total Treatment Cost for Division 5

System	Total Cost	Percentage (%)
Interstates	$ -	0.0
U.S.	$ 36,679,354.00	10.3
NC	$ 25,825,366.00	7.2
SR	$ 294,255,526.00	82.5
Total	$ -	0.0

Table A-21: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 27,497,469.00	12.3
NC	$ 17,174,996.00	7.7
SR	$ 179,425,270.00	80.1

Total	$ 224,097,735.00	100.0

Table A-22: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 9,181,885.00	6.9
NC	$ 8,650,370.00	6.5
SR	$ 114,830,256.00	86.6
Total	$ 132,662,511.00	100.0

Table A-23: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	0
Fund II	62.8
Fund III	37.2

Division 7

Table A-24: Total Treatment Cost for Division 7

System	Total Cost	Percentage (%)
Interstates	$ 8,289,560.00	3.1
U.S.	$ 23,206,276.00	8.7
NC	$ 20,769,585.00	7.8

SR	$ 213,388,836.00	80.3
Total	$ 265,654,257.00	100.0

Table A-25: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 8,289,560.00
Total	$ 8,289,560.00

Table A-26: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 16,740,946.00	11.0
NC	$ 16,253,094.00	10.7
SR	$ 118,744,843.00	78.3
Total	$ 151,738,883.00	100.0

Table A-27: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 6,465,330.00	6.1
NC	$ 4,516,491.00	4.3
SR	$ 94,643,993.00	89.6
Total	$ 105,625,814.00	100.0

Table A-28: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	3.1
Fund II	57.1
Fund III	39.8

Division 8

Table A-29: Total Treatment Cost for Division 8

System	Total Cost	Percentage (%)
Interstates	$ 8,087,939.00	2.7
U.S.	$ 58,282,415.00	19.2
NC	$ 32,089,719.00	10.6
SR	$ 204,800,897.00	67.5
Total	$ 303,260,970.00	100.0

Table A-30: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 8,087,939.00
Total	$ 8,087,939.00

Table A-31: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 49,072,707.00	29.3
NC	$ 24,840,371.00	14.8
SR	$ 93,762,665.00	55.9
Total	$ 167,675,743.00	100.0

Table A-32: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 9,209,708.00	7.2
NC	$ 7,249,348.00	5.7
SR	$ 111,038,232.00	87.1
Total	$ 127,497,288.00	100.0

Table A-33: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	2.7
Fund II	55.3
Fund III	42.0

Division 9

Table A-34: Total Treatment Cost for Division 9

System	Total Cost	Percentage (%)
Interstates	$ 1,697,577.00	1.1
U.S.	$ 15,786,116.00	9.8
NC	$ 17,899,300.00	11.1
SR	$ 125,409,264.00	78.0
Total	$ 160,792,257.00	100.0

Table A-35: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 1,697,577.00
Total	$ 1,697,577.00

Table A-36: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 13,523,120.00	22.8
NC	$ 14,594,459.00	24.6
SR	$ 31,313,807.00	52.7
Total	$ 167,675,743.00	100.0

Table A-37: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 2,262,996.00	2.3
NC	$ 3,304,841.00	3.3
SR	$ 94,095,457.00	94.4
Total	$ 99,663,294.00	100.0

Table A-38: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	1.1
Fund II	37.0
Fund III	62.0

Division 10

Table A-39: Total Treatment Cost for Division 10

System	Total Cost	Percentage (%)
Interstates	$ 24,804,088.00	9.4
U.S.	$ 37,723,410.00	14.2
NC	$ 52,094,792.00	19.7

SR	$ 150,295,144.00	56.7
Total	$ 264,917,434.00	100.0

Table A-40: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 24,804,088.00
Total	$ 24,804,088.00

Table A-41: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 30,049,304.00	20.1
NC	$ 40,756,667.00	27.3
SR	$ 78,414,603.00	52.5
Total	$ 149,220,574.00	100.0

Table A-42: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 7,674,106.00	8.4
NC	$ 11,338,125.00	12.5
SR	$ 71,880,541.00	79.1
Total	$ 90,892,772.00	100.0

Table A-43: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	9.4
Fund II	56.3
Fund III	34.3

Division 11

Table A-44: Total Treatment Cost for Division 11

System	Total Cost	Percentage (%)
Interstates	$ 8,536,364.00	4.1
U.S.	$ 29,570,184.00	14.3
NC	$ 26,360,356.00	12.7
SR	$ 142,717,588.00	68.9
Total	$ 207,184,492.00	100.0

Table A-45: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 8,536,364.00
Total	$ 8,536,364.00

Table A-46: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 25,312,700.00	43.4
NC	$ 24,229,230.00	41.5
SR	$ 8,831,482.00	15.1
Total	$ 58,373,412.00	100.0

Table A-47: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 4,257,484.00	3.0
NC	$ 2,131,126.00	1.5
SR	$ 133,886,106.00	95.4
Total	$ 140,274,716.00	100.0

Table A-48: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	4.1
Fund II	28.2
Fund III	67.7

Division 12

Table A-49: Total Treatment Cost for Division 12

System	Total Cost	Percentage (%)
Interstates	$ 5,154,058.00	2.4
U.S.	$ 22,955,573.00	10.9
NC	$ 45,599,355.00	21.6
SR	$ 137,003,322.00	65.0
Total	$ 210,712,308.00	100.0

Table A-50: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 5,154,058.00
Total	$ 5,154,058.00

Table A-51: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 17,751,275.00	17.3
NC	$ 36,654,731.00	35.6
SR	$ 48,473,659.00	47.1
Total	$ 102,879,665.00	100.0

Table A-52: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 5,204,298.00	5.1
NC	$ 8,944,624.00	8.7
SR	$ 88,529,663.00	86.2
Total	$ 102,678,585.00	100.0

Table A-53: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	2.4
Fund II	48.8
Fund III	48.7

Division 13

Table A-50: Total Treatment Cost for Division 13

System	Total Cost	Percentage (%)
Interstates	$ -	0.0
U.S.	$ 37,252,519.00	14.4
NC	$ 28,184,114.00	10.9
SR	$ 193,414,925.00	74.7

Total	$ 258,851,558.00	100.0

Table A-51: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 25,589,186.00	19.5
NC	$ 21,517,777.00	16.4
SR	$ 83,851,709.00	64.0
Total	$ 130,958,672.00	100.0

Table A-52: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 11,663,333.00	9.1
NC	$ 6,666,337.00	5.2
SR	$ 109,563,216.00	85.7
Total	$ 127,892,886.00	100.0

Table A-53: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	0
Fund II	50.6
Fund III	49.4

Division 14

Table A-54: Total Treatment Cost for Division 14

System	Total Cost	Percentage (%)
Interstates	$ -	0.0
U.S.	$ 49,946,972.00	19.8
NC	$ 26,228,360.00	10.4
SR	$ 175,741,890.00	69.8
Total	$ 251,917,222.00	100.0

Table A-55: Treatment Cost for Fund I

Fund I	Treatment Cost
Interstates	$ 5,154,058.00
Total	$ 5,154,058.00

Table A-56: Treatment Cost for Fund II

Fund II	Treatment Cost	Percentage
U.S.	$ 43,141,543.00	38.1
NC	$ 22,596,360.00	20.0
SR	$ 47,427,910.00	41.9
Total	$ 113,165,813.00	100.0

Table A-57: Treatment Cost for Fund III

Fund III	Treatment Cost	Percentage (%)
U.S.	$ 6,805,429.00	4.9
NC	$ 3,632,000.00	2.6
SR	$ 128,313,980.00	92.5
Total	$ 138,751,409.00	100.0

Table A-58: Percentages of Fund Allocated for each Fund type

Type	Percentages (%)
Fund I	0
Fund II	44.9
Fund III	55.1

APPENDIX B: BUDGET ALLOCATION BY REGIONS, DIVISIONS & FUNDTYPES

Fund Allocation for Mountains region

Table B-1: Mountains Fund I

Division	Treatment Cost Percentages		
	Maintenance	Resurfacing	Other preservation
11	96.6	0	3.4

Table B-2: Mountains Fund II

Divisions	Treatment Cost Percentages	
	Mill Fill	Overlay
11	37.0	63.0
13	50.2	49.8
14	45.1	54.9

Table B-3: Mountains Fund III

Divisions	Treatment Cost Percentages							
	Single seal	Double seal	Triple Seal	Fog seal	Slurry Seal	Seal Crack	Wheel Patching	Full depth patching
11	0.3	35.9	22.2	0	0.1	13.8	6.1	21.6
13	0.3	18.3	10.8	0	0.2	33.4	19.3	17.6
14	0.3	16.0	43.4	0	0.2	20.4	9.4	10.2

Fund Allocation for the Piedmont region

Table B-4: Piedmont region Fund I

Division	Treatment Cost Percentages		
	Maintenance	Resurfacing	Other preservation
7	91.2	7.0	1.8
8	96.8	2.5	0.7
9	0	98.4	1.6
10	100	0	0
12	100	0	0

Table B-5: Piedmont region Fund II

Divisions	Treatment Cost Percentages	
	Mill Fill	Overlay
5	78.2	21.8
7	50.2	49.8
8	47.7	52.3
9	43.1	56.9
10	68.8	31.2
12	48.4	51.6

Table B-6: Piedmont region Fund III

Divisions	Treatment Cost Percentages							
	Single seal	Double seal	Triple Seal	Fog seal	Slurry Seal	Seal Crack	Wheel Patching	Full depth patching
5	0.1	24.3	1.7	0.4	0.3	40.9	18.8	13.3
7	1.5	31.8	2.5	0.0	0.0	33.8	19.7	10.7
8	0.8	23.4	7.7	0.1	0.0	35.3	18.4	14.3
9	0.9	28.5	29.0	0.0	0.1	16.4	8.8	16.2
10	0.7	23.4	19.3	0.0	0.0	30.4	14.9	11.4
12	0.6	26.2	18.8	0.0	0.3	25.8	18.3	10.0

Fund Allocation Coastal Plains region

Table B-7: Coastal Plains region Fund I

Division	Treatment Cost Percentages		
	Maintenance	Resurfacing	Other preservation
1	100.0	0.0	0.0
2	0.0	0.0	0.0
3	100.0	0.0	0.0
4	100.0	0.0	0.0
6	88.7	9.4	0.6

Table B-8: Coastal Plains region Fund II

Divisions	Treatment Cost Percentages	
	Mill Fill	Overlay
1	50.1	49.9
2	33.4	66.6
3	28.6	71.4
4	39.4	60.6
6	62.4	37.6

Table B-9: Coastal Plains region Fund III

Divisions	Treatment Cost Percentages							
	Single seal	Double seal	Triple Seal	Fog seal	Slurry Seal	Seal Crack	Wheel Patching	Full depth patching
1	0.3	15.6	4.1	0.3	0.1	36.5	29.1	13.9
2	0.1	13.0	17.4	0.3	0.1	33.0	20.9	15.1
3	0.1	10.1	22.5	0.1	0.1	33.9	11.4	21.8
4	0.3	22.6	0.4	0.1	0.1	42.1	27.4	7.1
6	0.2	14.9	1.2	0.4	0.6	49.5	25.9	7.3