# DEVELOPMENT OF A HIGHWAY MAINTENANCE COST INDEX

by

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# ABSTRACT

AUSTIN RICCIO. Development of a highway maintenance cost index. (Under the direction of DR. JOHN HILDRETH)

The North Carolina Department of Transportation records maintenance activities performed in house, but does not have an efficient way of forecasting future costs. The problem with not having an efficient way to forecast future highway maintenance costs is the inability to budget and plan for the changing cost over time. Due to this a cost index specific to highway maintenance was developed. Currently there are no other types of indices that relate to highway maintenance. Although there are indices available that relate to construction, they are not sufficient enough to be used for highway maintenance. The development of the highway maintenance cost index allows the NCDOT to be able to budget for future highway maintenance costs. The MCI values were calculated using a Laspeyres index formula. The Laspeyres index uses a set basket of goods from the base year, in order to estimate and track the change in money spent each year depending on the current year cost. With the given data a MCI tool was created in the form of an excel spreadsheet. Four sub-category indexes were developed including bridge, maintenance, traffic, and roadside maintenance. Using these four sub-category indexes one overall maintenance cost index (MCI) was created. Available data provided by the North Carolina Department of Transportation (NCDOT), from 2012 to 2015 was used in order to determine the base year variables for the index formula. The NCDOT will be able to use the provided MCI tool to better track, budget, and plan for future in house maintenance costs.

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# CHAPTER 1: INTRODUCTION

The North Carolina Department of Transportation (NCDOT) tracks and records maintenance activities performed in house by the NCDOT. Although these activities are recorded, there is currently no way of estimating the cost associated with these activities. Due to this it has been requested that a plan for estimating cost be developed for highway maintenance performed in house by the NCDOT. Currently many DOTs are using several different types of cost indices to estimate the costs of their maintenance activities despite the fact that the indices being used are not related to highway maintenance costs. Since the indices being used are not specifically related to the type of work being performed they are not accurate in estimating the future costs of the activities.

In order to fix this problem, a Maintenance Cost Index (MCI) was developed specific to in house highway maintenance costs. More specifically, the created MCI is for maintenance activities that are paid out of the standing maintenance budget by the NCDOT. This budget includes all tasks that are performed in house by the NCDOT and does not include contracted out work. Along with this MCI value, a tool was created for the NCDOT to use for future years. The tool allows the user to analyze past trends to aid in budgeting for future trends when it comes to highway maintenance costs.

## 1.1 Problem Statement

The North Carolina Department of Transportation (NCDOT) develops three to five year plans of the estimated timing and cost for highway preservation, rehabilitation, and maintenance work. The problem is, there is currently not an efficient way of doing this. It is important for transportation agencies to be able to create a way to estimate and track the costs for transportation systems in order for them to determine how much money should be budgeted for future costs. The costs associated with transportation infrastructure throughout the life cycle of the transportation system includes the construction costs, rehabilitation costs, and maintenance costs. In 2012, the United States spent approximately $105.2 billion in total capital outlay for highways by all units of government (Office of Highway Policy Information 2014). In the same period, maintenance expenditures totaled approximately $48 billion (Office of Highway Policy Information 2014). Due to the fact that almost half of the total capital outlay is spent on highway maintenance each year, it is obvious that highway maintenance needs to be included in the short term budget for the transportation system.

Maintenance costs can be categorized by the different means of performance, including maintenance performed by outside forces under contract and maintenance performed in house by the DOT. Maintenance work performed in house by the DOT includes, but is not limited to, maintenance tasks performed by personnel who are directly employed by the DOT. The maintenance work contracted out has already been indexed in the past, therefore the need to develop a cost index specific to work that is contracted out is not necessary. Also work that is contracted out does not have to be analyzed the same way as the in house work. The work that is contracted out is tracked similar to new construction work, in that they are both contracted out using the competitive bid process. Due to the competitive bidding process that is used, there is simply just the final price of the work done that has to be recorded and analyzed. While in order to track the in house work performed there are several pieces of data that are needed to calculate the index, such as total price, total quantity, and unit cost. Although the National Highway Construction Cost Index (NHCCI) may be appropriate for maintenance work that is contracted out because it is based on construction costs, it is not specific enough to accurately represent the maintenance work performed in house. The work that is performed in house by the DOT has different work tasks that have to be recorded based on the cost of labor, equipment, and materials and there is no current way to track and index this process.

Due to the need to budget and plan for highway maintenance costs performed in house, transportation agencies have attempted to compensate for the issue by using other indices. The use of the Consumer Price Index published by the US Bureau of Labor Statistics and other highway construction indices have been applied to highway maintenance. Ozbek (2007) stated such an index is less than ideal because it is not specific to highway maintenance. For example, when the NC Highway Construction Cost Index table of Consumer Price Index was used to adjust the amount of resurfacing funds needed in 2010, the adjusted amount was 57% higher than what was actually allocated (Conti et al. 2010). The current types of cost indices that are available are not specific to highway maintenance and, therefore, do not accurately reflect cost trends for in house work. A cost index pertaining to in house highway maintenance is needed in order to better budget and plan for changing costs over time. Benefits of having a cost index specific to highway maintenance include providing a way to compare trends in maintenance costs, being able to prepare accurate maintenance budgets, and forming good financial decisions. A cost index specific to highway maintenenace is vital in planning for future budgets and tracking past and future costs.

The Federal Highway Administration (FHWA) established the highway and operations cost index in 1947, but never revisited the original basket of goods. After a study was conducted in 1990, it was determined that the cost index would be discontinued due to differing opinions on whether or not it was useful due to things such as lack of use and lack of data quality (Markow et al. 1990). Although the index was discontinued, the need for an updated maintenance cost index has continued to surface over the past 25 years.

The NCDOT currently maintains task level data of maintenance activities that are performed in house. Costs of maintenance vary from year to year due to the variation of resource costs. Resource cost can vary depending on supply and demand of the different resources being used during the maintenance process. The opportunity to develop a maintenance cost index (MCI) arises due to the fact that the NCDOT currently tracks and maintains the data needed for development.

Estimating the cost of future work requires knowledge of the current and past trends in maintenance costs. The need for a maintenance cost index specific to highway maintenance has been proven necessary for several different reasons, one of which includes the fact that it was previously recognized by the FHWA. Also, the fact that the NCDOT currently uses other cost indices to track and predict maintenance costs that do not produce accurate index values. Lastly, the NCDOT currently tracks and records all the necessary data needed to create an MCI.

# CHAPTER 2: SCOPE AND LIMITATIONS

The goal of this research was to develop a maintenance cost index useful for improving the accuracy of highway maintenance budgets. The research will be used to develop a three to five year work plan for preservation, rehabilitation, and maintenance work. The proposed outcome was completed through achieving the following objectives.

Objective 1 – Determine appropriate cost index formula

The first objective that was completed was determining which type of cost index would be used to complete the maintenance index. In doing this, three different indices were considered, the Laspeyres, Paasche, and Fisher indices. The advantages and disadvantages were taken into account for the proposed scope of work for each index.

Objective 2 – Identifying the basket of goods

After the index was chosen, the basket of goods was determined. A basket of goods is a small set of tasks that represent the whole. The basket of goods was determined based on whether or not the activities are specifically maintenance related, they have the appropriate unit of measure, the activity is currently performed, the activity is a significant expenditure, and the activity has quality records. There are four different sub-categories including maintenance, roadside, traffic, and bridge. Each of these required their own basket of goods.

Objective 3 – Determining the base year parameters

Once the basket of goods was determined for each of the four sub-categories, the base year parameters were calculated for the selected cost index formula. The two base year parameters that needed to be calculated in order to use the selected cost index formula are the representative unit cost and the representative annual quantity performed for each work activity in the base year. These two parameters are the basis for the cost index and were estimated based on the work task data provided. By calculating these two base year parameters, the user will only need to determine either the unit cost or the quantity of the work activity for the year being calculated for depending on the index being used.

Objective 4 – Creating a Composite cost index

The fourth objective that was completed was creating one composite cost index. This was done by combining all four sub-indices into one composite MCI. This was accomplished by calculating each index individually using its own basket of goods and then by combining each of the sub-category indices basket of goods into one complete total basket of goods. The reason this was necessary is so the NCDOT will be able to keep track of the total in house maintenance cost index values over time as well as the individual sub-category indices.

Objective 5 – Demonstrate calculation of indices

The fifth objective in completing the cost index was demonstrating data management and the calculation process of the indices. To accomplish this, an Excel spreadsheet tool was created using work task data from 2012 to 2015. The process for managing the data and calculating the indices was demonstrated using this data and the developed Excel spreadsheet tool. This provides the NCDOT with an example of how to use the MCI tool so they can better understand the process that goes into calculating the cost index value.

## 2.1 Limitations

In order to complete the development of the MCI, the work task data provided by the NCDOT was used. This includes maintenance activities from years 2012 to 2015, paid for out of the standing maintenance budget. As stated before, this budget only includes maintenance activities that are performed in house by the DOT. Only maintenance activities performed by the NCDOT will be used. This means that the indices created will only be of use by the NCDOT. Furthermore, it was decided that four separate indices would be created due to the fact that the NCDOT categorizes their maintenance activities into four separate categories. These categories include roadside, traffic, maintenance, and bridge activities. Along with these four indices, it was also decided that a fifth index would be developed to combine all four of the sub-categories into one main composite index. Also, it was determined that 2014 would be the base year for the indices because this was the most current year available at the beginning of the development process.

# CHAPTER 3: LITERATURE REVIEW

Qasim et al. (1992) said "the most common method used to adjust cost estimates from one geographic location and time period to another is the cost index." A cost index is a ratio of the difference in value from one time, location, or quantity to another. Cost indices can measure several different things including labor, operation, equipment, commodities, maintenance and several other types of costs (Remer et al. 2008). Remer et al. (2008) reported that cost indices were first developed in 1750 and are still being used today. Cheng et al. (2009) stated that the best way to accurately accommodate changes in bid items and contracts is by using a cost index. A cost index can be composed of multiple goods in order to establish a single composite measure of cost. Without the use of cost indices it would be nearly impossible to budget, plan, and track the change in prices from one year to the next.

## 3.1 Cost Indices

A cost index is used to compare the current price of a certain basket of goods to the price of a base year. Sharma et al. (2013) said "it is important to use the correct index for the particular cost updates." There are three common types of cost indices which are, the Laspeyres, the Paasche, and the Fisher cost indices. All three of these indices have advantages and disadvantages when forming a cost index for highway maintenance work.

The first type of cost index is the Laspeyres index. The equation for the Laspeyres index is as follows:

$$I_{Lt} = 100 * \frac{\sum_{j=1}^{n} p_{jt} q_{j0}}{\sum_{j=1}^{n} p_{j0} q_{j0}}$$ Equation 1

Where: $I_{Lt}$ = cost index in year $t$

$p_{jt}$ = price of good $j$ in year $t$

$p_{j0}$ = price of good $j$ in the base year 0

$q_{j0}$ = quantity of good $j$ in the base year 0

The Laspeyres index is a direct relation of the price of the basket of goods in the base year to the price of the basket of goods in its current year. The base year index will have a value of 100 and any value greater than 100 indicates an increase in price, and any value below 100 indicates a decrease in price. For example, the base year value will be 100, if the index in 2015 is 125 that means the price of the basket of goods has increased by 25% over the price in the base year. The main advantage of the Laspeyres cost index is that it is easy to calculate timely figures. Once the information for the base period (prices and quantities) is established, only the prices for the current period being investigated need to be updated. The Laspeyres index calculates the total cost of a basket of goods based on the base period price without the substitution of its commodities due to price change (Braithwait 1980).

The second type of cost index is the Paasche index, it is used to calculate the price of the current basket of goods at the price they would have been in the past. The Paasche index calculates the current year index using current year quantities, where the Laspeyres index uses the base year quantities. The difference in using base year quantities and current year quantities is that using base year quantities better represents the price ratio of current price to base year price. The equation for the Paasche index is as follows:

$$I_{pt} = 100 * \frac{\sum_{j=1}^{n} p_{jt} q_{jt}}{\sum_{j=1}^{n} p_{j0} q_{jt}} \quad \text{Equation 2}$$

Where: $I_{pt}$ = cost index in year $t$

$p_{jt}$ = price of good $j$ in year $t$

$p_{j0}$ = price of good $j$ in the base year 0

$q_{jt}$ = quantity of good $j$ in year $t$

The Fisher index takes into account both the Laspeyres and the Paasche index and is the geometric mean of the two. Diewert (1998) states that the Laspeyres index tends to overstate the rise in the cost of the basket of goods whereas the Paashe index does the opposite and understates the cost of the basket of goods. Thus the Fisher index is an index that averages the Paasche and the Laspeyres index together. The equation for the Fisher index is as follows:

$$I_{Ft} = \sqrt{I_{Lt} * I_{Pt}} \quad \text{Equation 3}$$

Where: $I_{Ft}$ = cost index in year $t$

$I_{Lt}$ = Laspeyres index

$I_{Pt}$ = Paasche index

The Fisher and Paasche indices take into account how the price of an item affects the demand of that product. The Fisher index allows for a change in the basket of goods based on current demand, and the Paasche index takes into account the demand of the product. The Paasche index often underestimates price increases while the Laspeyres index often overestimates the price increases.

The disadvantage of the Fisher and the Paasche indices is that it is believed that the basket of goods and their demand for highway maintenance is not going to change due to price changes (Diewert 1998). For example, just because the price of asphalt increases, the NCDOT is still going to have to use asphalt for certain maintenance purposes.

### 3.2 Construction Cost Indices

In the past, construction cost indices have been used to assist budgeting and planning for highway maintenance. Wilmot et al. (2005) stated that the overall measures of highway construction costs are construction cost indices. Construction cost indices are typically used to follow the historical change in the cost of construction from past years to the present (Wilmot et al. 2005). The two most common construction cost indices include the Building Cost Index (BCI) and the Construction Cost Index (CCI) published by the Engineering News-Record (ENR). Remer et al. (2008) reported that the ENR is the oldest inflation index used by engineers and was started in 1909. Wilmot et al. (2003) stated these types of indices are typically used for short term budgeting because they are based on the assumption that past conditions remain constant in future trends. They also stated that in order to prepare for highway construction programs, one must be able to accurately estimate future funding and project cost. Also, that it is the estimation process that often disarrays the process of the construction programs. Through the use of a cost indices a cost estimator could use construction cost data from one building, built in a certain city in a certain year, and estimate the cost of another building of different capacity in a different city and different year (Remer et al. 2008).

The Bureau of Labor Statistics reports that the Producer Price Index (PPI) is the average change in selling prices received by domestic producers for their output over a period of time (Latest PPI News Releases). The PPI only takes into account the selling price of certain goods, and not the whole price necessary to complete a task which is why it is negligible when it comes to a maintenance cost index.

Another price index is the Composite Bid Price Index for Highway Construction (BPI) which is composed of six base indicator items. These six base indicators are all major highway construction items (Ozbek 2007). The contract prices on which this cost index is based include cost of materials, labor, equipment, and profit made. The FHWA only requires states to report projects with a total contract value greater than $500,000. These contracts are then compiled over three consecutive quarters in order to create the cost index for each state (FHWA 2006). The BPI has a base year of 1987 and was on a steady incline from 1987 until its end in 2006. Figure 1 shows this steady incline and the index values from 1972 to 2006.

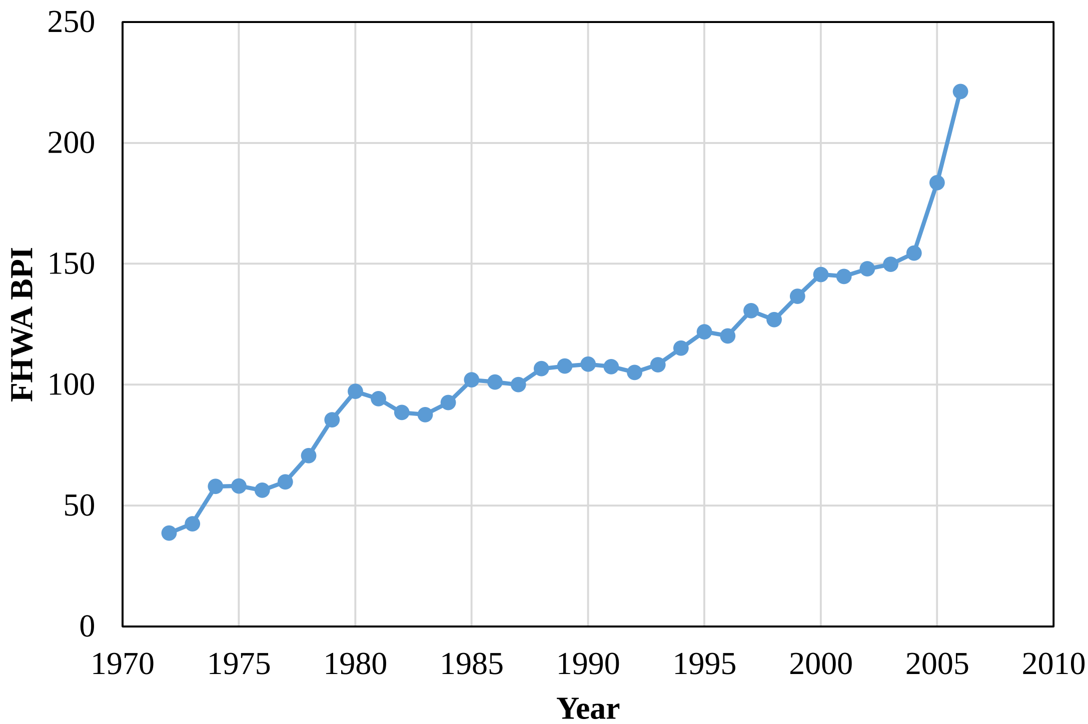


FIGURE 1: Federal Highway Administration BPI

The cost of inflation associated with roadway construction and maintenance can be tracked using the FHWA's BPI. The BPI uses a Laspeyres index to demonstrate the changes in price of highway construction goods based on a 1980 basket of goods. In doing this, one can see a steep upward trend in cost between 2003 and 2006, as shown in Figure 2. The main resources that caused this increase in construction and maintenance cost can be attributed to steel, cement, and asphalt. With the implementation of the proposed cost index, an upward trend in the cost like the one shown in Figure 2 could be budgeted for **(**Transportation Cost and Benefit Analysis II 2013).

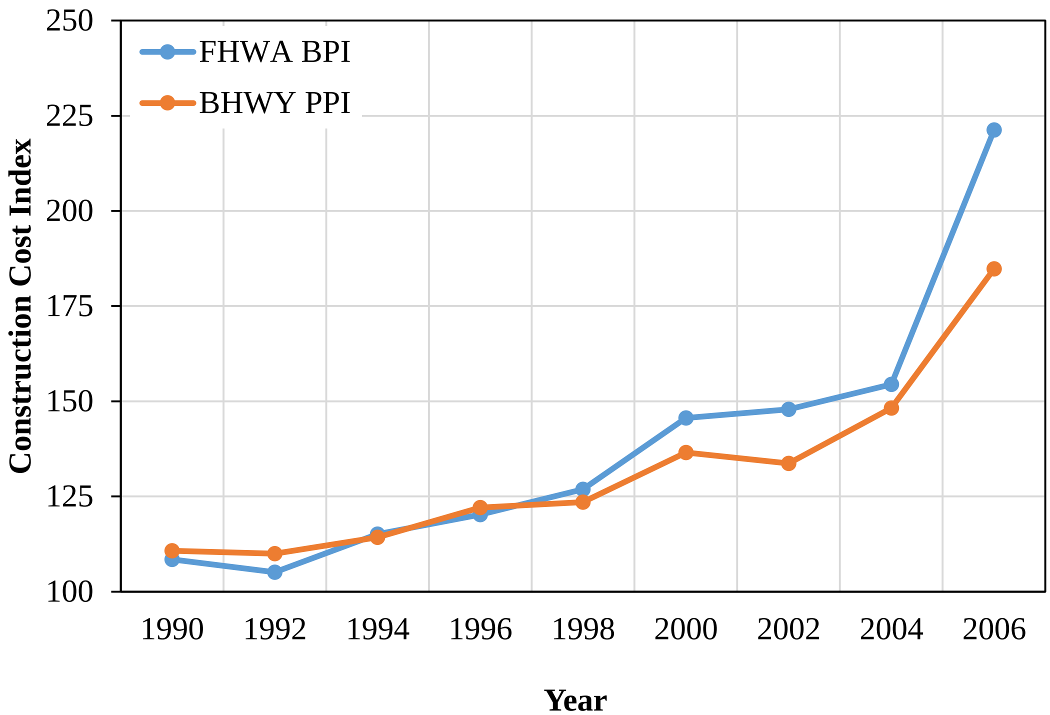


FIGURE 2: US highway construction cost indices

The National Highway Construction Cost Index (NHCCI) replaced the Federal Highway Administrations (FHWA) bid price index in 2006. The NHCCI is used to monitor the changes in price due to highway construction costs and to establish the current price of highway construction costs based on past costs. The NHCCI uses a Fisher index to produce results that are based on construction costs, and that are reliable based on the comparison of relatable cost indices (NHCCI, 2015). As seen in Figure 3, the NHCCI has a base year of 2003 and had two peaks from 2005 to 2009 but then leveled off and remains somewhat consistent.

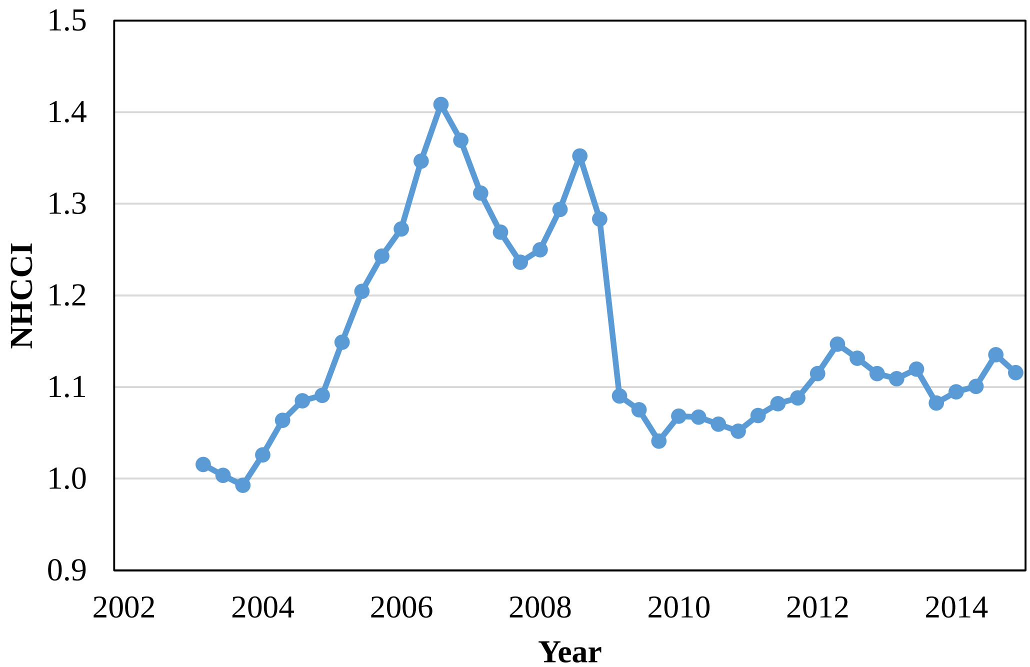


FIGURE 3: National Highway Construction Cost Index

The main difference in the NHCCI and the BPI is that the NHCCI takes into account all contract bids while the BPI is only based on data from contracts over $500,000. Figure 4 shows the percent difference in the contract bid prices from one year to the next, between the BPI and the NHCCI. One can see the quarterly spikes in the BPI due to the final completion of projects, unlike the NHCCI which is more accurate due to the fact that it uses the actual contract bid prices. The main difference between the NHCCI and the PPI is that the NHCCI better represents a construction cost index whereas the PPI better represents a sales price index (White, 2011). Although the NHCCI is clearly a better construction cost index than the PPI and the BPI, it is not sufficient to use as a highway maintenance cost index. This is because it is calculated using a Fisher index, which is based off of the idea that the price of a good determines the quantity purchased, and is also based off of construction tasks and not maintenance tasks.

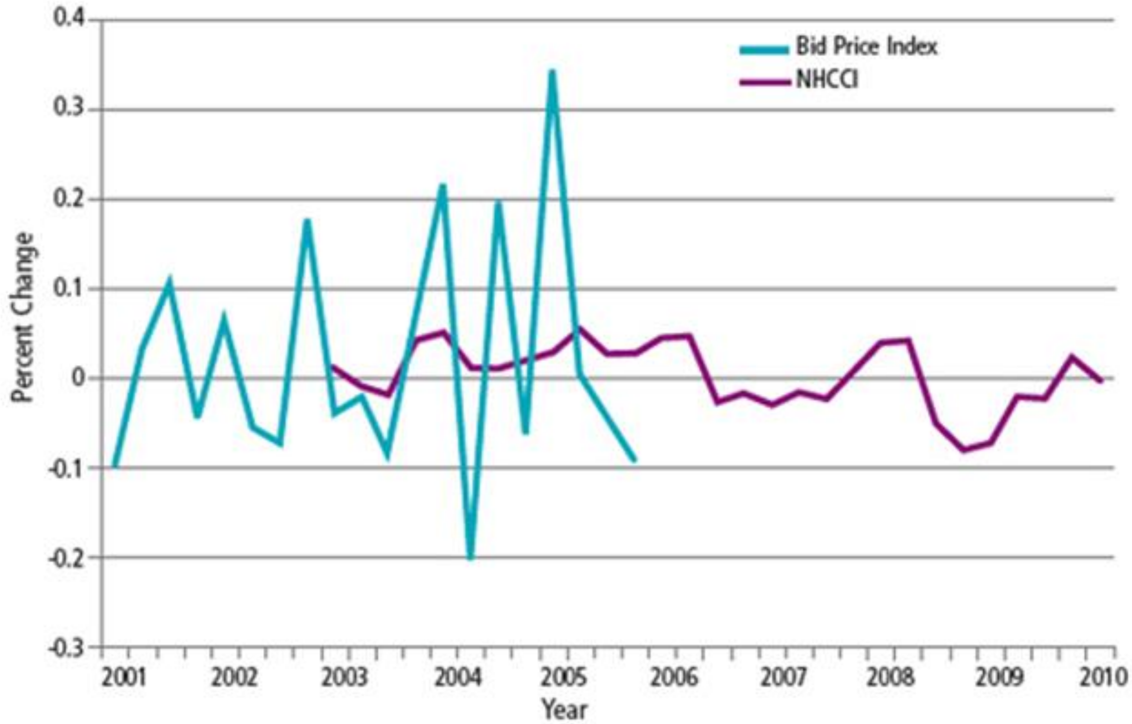


FIGURE 4: Comparison of new FHWA construction cost index to retired BPI (White 2011)

Wilmot and Cheng (2003) developed the Louisiana Highway Construction cost index. The index is a composite measure of resource costs, contract characteristics, and construction environment. The model allows one to predict future construction costs in Louisiana based on past construction costs. Although it allows for more accurate budgeting for future highway construction, it does not allow for accurate budgeting for highway maintenance costs. This is because the basket of goods and other factors that go into the construction of highways are different from the maintenance work for highways.

Conti (2010) discusses how the use of the NC Highway Construction Cost Index table of the Consumer Price Index would cause a much higher predicted dollar amount than the actual amount spent. One can see in Figure 5 the amount allocated for contract resurfacing is approximately 57% higher than the CPI adjusted value calculated using the construction cost index table. The result of this inaccuracy would cause a huge decline in purchasing power. This proves that the use of construction cost indices to budget for maintenance costs is inaccurate and should not be used. Conti (2010) found from 2000-2010 the paved lane mile increased by 4% and the bridge deck area increased by 24%. Although the maintenance funds have increased along with the growth, the funds have not increased enough to keep up with the growth and the inflation rate. Part of the reason for this is the lack of a way to accurately calculate highway maintenance costs.

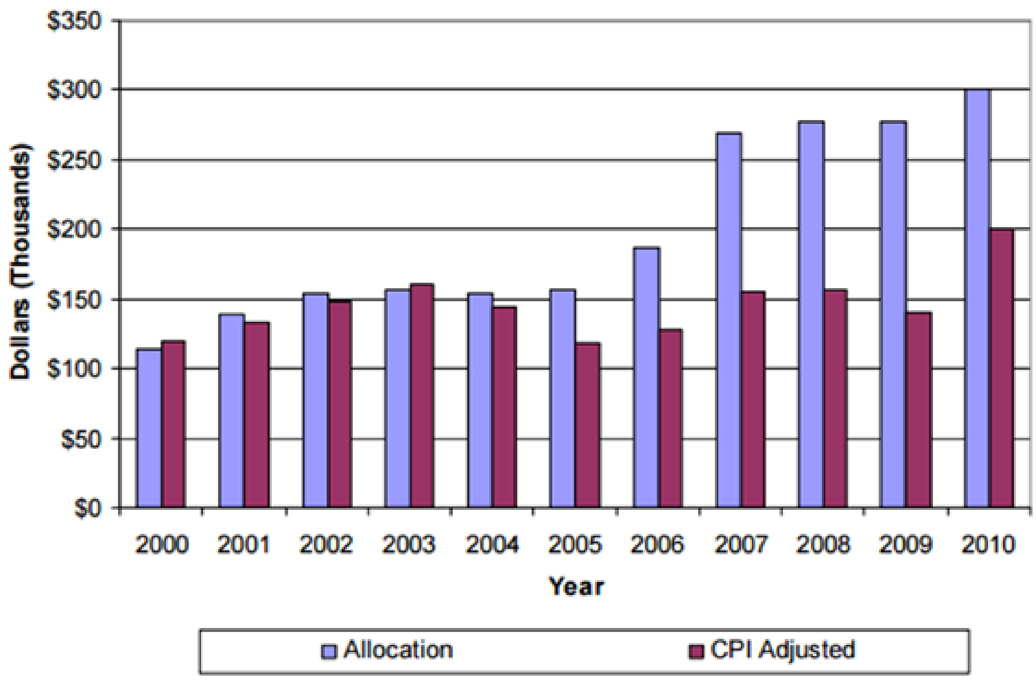


FIGURE 5: Contract resurfacing: allocation compared to CPI adjusted (Conti 2010)

Construction cost indices have been used in the past to help budget for maintenance cost but they are not specific enough to highway maintenance. Due to this, using a construction cost index in order to budget and plan for highway maintenance is far from accurate. Wilmot et al. (2005) stated that it is important for construction programs to not deviate from the original construction plan. This is because any deviation shows a lack of accuracy in the DOT and in turn can cause the DOT to lose credibility and funding.

### 3.3 Highway Maintenance Cost Indices

Markow (1990) discussed the highway maintenance and operations cost index that was previously used from 1947-1990. This cost index was developed by FHWA in 1947 and published annually. However, it was never revised over its 43 year life. The index had a base year of 1947 and was used until its discontinuation in 1990. Although the index was published in 1947 Figure 6 shows the available data from 1960 to 1990. This Figure shows the steady incline in price from 1960 to 1990.

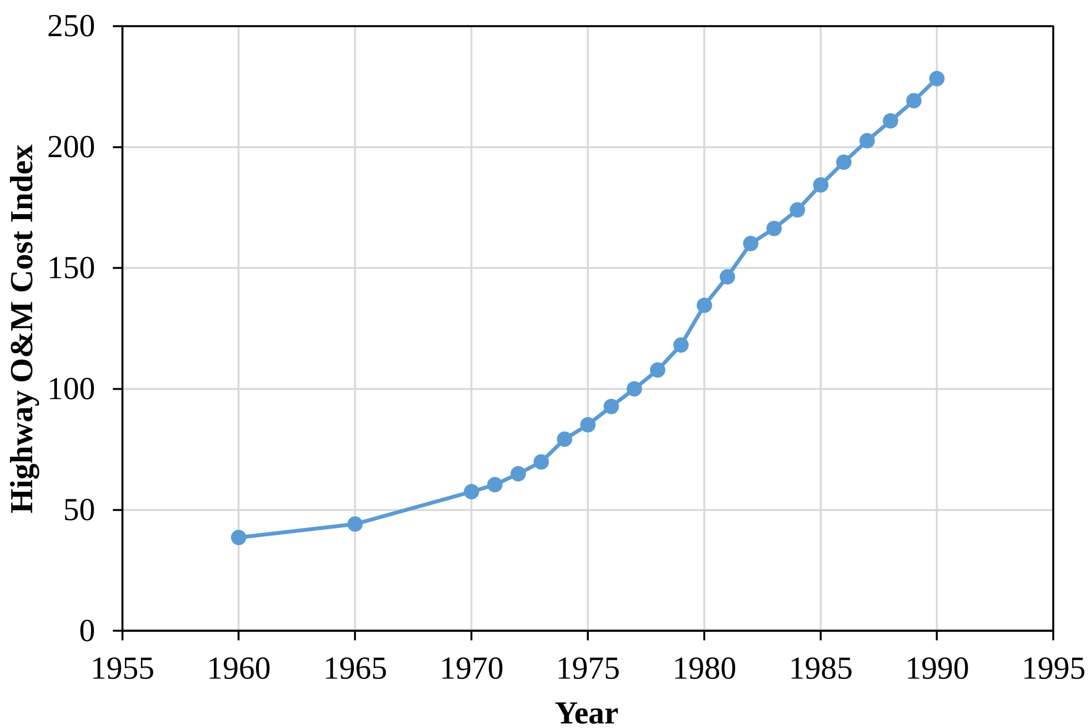


FIGURE 6: Highway Operations & Maintenance Cost Index

Kassabian et al. (1990) conducted a study to determine the best approach to take with this cost index on whether or not it should be revised or discontinued and the most favorable approach was to redevelop it. The study surveyed nine different state DOTs on their opinion regarding the usefulness of the current index. Some of these DOTs relied on it heavily, while others rarely even looked at it. The five DOTs that reported relying on it heavily used it for planning, budgeting, finance, and construction purposes. One state even used the index in order to determine the motor fuel tax rate from year to year. The main conclusion that was drawn from the study was that the market basket needed to be revised from its original 34 items to approximately 10 to 20 items. The reason for this is so that it would be easier for the states to maintain and report the data necessary to keep the index accurate. Another revision that was suggested to be made is the current units used to measure the amount of certain materials did not match the units that the index used making it difficult to report accurate information. For example, the index required an input of dollars per barrel for cement, but cement is now priced by the ton. A third revision that was suggested is better directions for which items needed to be priced for different categories. The approach of revising the index would include long term collaboration between the states and the FHWA in order to keep the cost index up to date and accurate. Although all the states that actually used the index were in favor of keeping it, the FHWA ultimately chose to cancel the highway maintenance and operations cost index in 1990.

Markow (2011) presented a process to determine the full cost for performing highway maintenance. This full cost includes the cost of the work performance and the cost of all the necessary activities that go along with performing these tasks. One piece of useful information from the report is that the NCDOT has about 120 maintenance activities which was reduced from 700 in 2007. These items were reduced due to their lack of insight about the performed work. These 120 activities are categorized into four maintenance categories (previously six) which include roadside, maintenance, traffic, and bridge. Currently the NCDOT uses two different methods to record and manage their maintenance cost data. These two methods are the maintenance management system (MMS) and the financial management system (FMS). The FMS records data that includes labor, materials used, and equipment used. This information is entered into the FMS first and then is transferred into the MMS (Markow, 2011). Although the use of the FMS and the MMS help to keep track of the current and past maintenance costs, they do not provide a way for the NCDOT to budget and plan for future maintenance costs.

Adams (2011) conducted a study on maintenance condition and cost data for the Michigan, Ohio, and Wisconsin state highway agencies. This study collected and used data over a three year period from 2004 to 2006. She concluded that three years of data is not sufficient to define a trend overtime. Also the relationships between cost and condition are not clearly tied to the elements of the maintenance condition. The reason for this is that overtime the amount of vehicle miles traveled increases but the amount of money spent on highway maintenance decreases. This is a problem because the amount of money spent on highway maintenance should increase overtime as the amount of vehicle miles traveled increases.

Based on the past work that has been conducted one can see that the need for a cost index specific to highway maintenance is critical. Although there are several different types of cost indices available there is not any sufficient enough for highway maintenance. With the development of a highway maintenance cost index the ability to budget and plan for future cost pertaining to highway maintenance would be substantially easier and more accurate.

# CHAPTER 4: DEFINING THE COST INDEX

To develop the MCI, a cost index formula had to first be selected. The index formula needed to be representative of the desired outcome and selected based on the data provided by the NCDOT. The desired outcome was to develop an MCI for short term cost estimating. The standing maintenance work orders were used for this study because these work tasks are performed in house by the NCDOT and paid for out of the standing maintenance budget. Any tasks that are not performed by the NCDOT, and are contracted out, are not included because they are tracked using separate methods. Also, the maintenance activities included in the basket of goods were reduced to represent all maintenance activities performed in house by the NCDOT.

## 4.1 Index Formula Selection

Three different index formulas were considered for the MCI value calculations: the Paasche, Laspeyres, and the Fisher index. The Laspeyres index was selected because the index is calculated based on the current year unit cost of a basket of goods that does not change over time.

The basket of goods should not change because the NCDOT will continue to use the same maintenance activities in the future. It is important that the same basket of goods be used and not changed so a consistent cost estimate can be calculated from year to year The Paasche and the Fisher indices take into account that the basket of goods may change from year to year. As stated before, the basket of goods will stay the same from year to year because the same activities will continue to be used for highway maintenance.

The Paasche index is based on the quantity in the current year and the unit cost in the base year. The purpose of the study is to track the change in cost from year to year as opposed to the change in quantity from year to year. Therefore, it was decided that the Paasche index would not be used. The Fisher index is a geometric mean of the Paasche and the Laspeyres indices, taking into account the current year quantity and the current year unit costs. It was determined that the index needed to be calculated based on the change in cost from year to year eliminating the Fisher index. The Laspeyres index is based on the current year unit cost as opposed to the current year quantity. This allows the index to reflect the change in cost from year to year as opposed to reflecting the change in quantity from year to year.

The developed cost index is a short term cost index and is to be used for estimating three to five years into the future. This is when the Laspeyres index is most accurate. Wilmot et al. (2005) stated that when the basket of goods remains the same, it is best for the index to be used for approximately five years or less. Due to these reasons, the Laspeyres index was chosen as the most representative index formula for the study.

## 4.2 Data Collection

The NCDOT uses six different categories when recording highway maintenance data including:

1. Pavement Seals
2. Roadside
3. Traffic

4. Maintenance
5. Bridge
6. Miscellaneous

Maintenance tasks, categorized as pavement seals, were not included in the research because a large percentage of the work orders performed under this category are contracted out and that percentage is expected to increase in the future. Maintenance tasks categorized as miscellaneous were not included in the research because these work orders were not directly related to the cost of highway maintenance. For example, activity “6030-Educational Expenses” and activity “6150-Drug and Alcohol Testing” are not directly related to highway maintenance.

Two sets of data provided by the NCDOT were used for this study, including the work activity summary data and the standing maintenance work order data. The work activity summary spreadsheet contained the total annual expenditures for the work activities performed for highway maintenance, but not the individual work orders. There were over 100 work activities included and the data covered activities from 2012 to 2014. This included all work pertaining to highway maintenance costs that are both contracted out and performed in house by the NCDOT. Table 1 shows the values from this data set for the total sum of money spent on the roadside activities for 2012 to 2014. The remaining work activities and costs associated with them can be found in Appendix A.

TABLE 1: Summary of annual roadside task expenditures

| Work Activity | 2012 | | 2013 | | 2014 | |
|---|---|---|---|---|---|---|
| | **Total Cost** | **Percent of Total Cost** | **Total Cost** | **Percent of Total Cost** | **Total Cost** | **Percent of Total Cost** |
| 2900-Grass Mowing | $23,390,151 | 28% | $23,539,552 | 29% | $25,095,788 | 32% |
| 2912-Brush and Tree Control / Mechanical/ Other | $21,013,137 | 25% | $16,605,185 | 20% | $15,448,687 | 20% |
| 2916-Roadside Vegetation Enhancement | $5,476,519 | 6% | $ 5,475,989 | 7% | $5,187,622 | 7% |
| 2914-Vegetation Management at Stationary Objects | $4,617,014 | 5% | $5,110,593 | 6% | $5,082,336 | 7% |
| 2918-Seeding and Mulching and Fertilization | $4,951,328 | 6% | $4,655,728 | 6% | $3,641,694 | 5% |
| 2904-Turf Management | $1,657,998 | 2% | $1,795,106 | 2% | $1,612,258 | 2% |
| 2908-Brush and Tree Control /Herbicides | $1,628,991 | 2% | $1,138,065 | 1% | $1,058,669 | 1% |

The standing maintenance work order data included records of the individual work orders that were performed for each of the work activities. This included the total quantity of work performed, total cost, unit cost, and other details about each individual work order performed such as dates and types of cost. From this data, it was possible to see that many of the individual work orders were missing cost and quantity data. The number of work orders recorded in 2014 for each activity in the roadside category is provided in Table 2, along with the number of records where cost and/or quantity data are included. This information was used when selecting the basket of goods as explained in section 4.3. Some of the work activities could not be included in the basket of goods because of the lack of data associated with them. One example of this is “3226-Long Line Specialty Material Pavement Markings” as seen in Appendix B, contained 38 total work orders in 2014 and 17 included a quantity and cost. The lack of work orders recorded does not allow for an overall representation of the work activity. A complete list of all the work activities and the number of work orders associated with them is provided in Appendix B.

TABLE 2: Summary of 2014 roadside work order data records

| Index | Task | No. of Work Order Records | | | |
|---|---|---|---|---|---|
| | | Total | Quantity & Cost | Quantity Only | Cost Only |
| Roadside | 2900-Grass Mowing | 355 | 311 | 22 | 22 |
| | 2904-Turf Management | 181 | 177 | 0 | 4 |
| | 2908-Brush and Tree Control /Herbicides | 98 | 92 | 0 | 5 |
| | 2912-Brush and Tree Control / Mechanical/ Other | 2,350 | 2,191 | 50 | 107 |
| | 2914-Vegetation Management at Stationary Objects | 906 | 808 | 5 | 93 |
| | 2916-Roadside Vegetation Enhancement | 109 | 108 | 0 | 1 |
| | 2918-Seeding and Mulching and Fertilization | 563 | 531 | 0 | 30 |

## 4.3 Preliminary Selection of Work Activities

The representative items used for the basket of goods in each sub-category were determined first. The "basket of goods" for this study is the minimal amount of work activities needed to represent all work activities performed in the standing maintenance category. Advantages and disadvantages arose when narrowing down the number of work activities included in the basket of goods. Advantages of fewer activities include a more user friendly tool and less room for error when tracking and recording data. Including more than enough activities is inefficient. By only using the top expenditures for the basket of goods, it is known that they are routinely performed and recorded, thereby increasing the accuracy of the data. The NCDOT should be able to record better data on repeated activities because they record and track these activities often. Due to these reasons, it was determined that the basket of goods would consist of as few work activities as possible while still maintaining the accuracy of the MCI values.

Five different criteria were considered when determining which work activities would be included in the selected basket of goods. These five criteria were applied to the data collected from the base year 2014. The first criteria was determining whether or not the work activity was maintenance related or paid for through a different budget. The activities used for the MCI are all funded out of the standing maintenance task budget. Some of the work activities provided were not specifically related to maintenance and were not considered for the index.

The second criteria was deciding if the task had the appropriate unit of measure. Several work activities were measured by the lump sum. Unit costs could not be calculated for these activities.

The third criteria was determining if the work activity was or is going to be discontinued in the near future. In the work order list provided, there were a few tasks that had already been discontinued. Also there were several tasks that were no longer going to be performed and therefore were not considered for the basket of goods.

The next criteria in deciding the basket of goods was the amount of data provided for each work activity. For example, some of the activities had a large total cost but there was a lack of data for each individual work order resulting in few or no individual records. Without the individual work order records there was no way of determining a unit cost or quantity. There were some work activities that were performed a small number of times. For example, “3368-Installation and Replacement of NBIS Pipes and Culverts” was only recorded six times in 2014. As a result, this activity is not representative of overall maintenance.

The last criteria for which work activities would be included in the basket of goods was determining if the activity was one of the significant expenditures. This was done using the work task summary spreadsheet. This spreadsheet included all the work activities and the total annual expenditures for years 2012 to 2014. After the above four criteria were met the top 80 percent of activities were included in the basket of goods. Meaning 80 percent of highway maintenance costs were kept. Using the top expenditures allowed for a more user friendly process. Meaning the NCDOT does not have to keep track of all the work activities that are involved in each sub-category. The top expenditures produce an accurate representation of all the work activities in each sub-category.

The above five criteria were applied to each of the four sub-categories to preliminarily select the number of work activities in each one. These five criteria made it possible to reduce the total number of work activities from 110 to 33. Reducing the number of the activities in the basket of goods makes it easier for the user to maintain the data and calculate an accurate MCI value. Table 1 shows the basket of goods for the roadside category after the first process of eliminating work activities was completed. Also in Table 1 is the total amount of standing maintenance costs associated with the work activities per year and the percentage of the total cost. These percentages represent the percent that was used when deciding the top 80% expenditures for each sub-category index as explained previously. Three tables in Appendix C were created for the other sub-categories in order to determine all the activities that met the five criteria explained previously.

## 4.4 Summary

The first thing that was completed to develop the MCI was determining the best cost index formula to use. After considering three types of formulas it was ultimately decided to use the Laspeyres index formula. The Laspeyres index was chosen because it is based on the current year unit cost of a basket of goods that does not change throughout its use.

The NCDOT records highway maintenance data in six different categories. The MCI being developed was broken down into four separate MCIs for four of the six categories as well as one MCI to account for all the maintenance work combined. These sub-category indices include roadside, traffic, maintenance, and bridge. To make the MCI tool more user friendly and efficient the least amount of activities will be included in the basket of goods while still producing accurate values. It was possible to reduce the number of activities from 110 to 33 by setting certain criteria and selecting the top 80 percent expenditures for each sub-category index. The next step in developing the MCI tool was to start calculating the values needed to develop the tool. These values will be needed for the selected index formula to be used.

# CHAPTER 5: DEVELOPMENT OF THE COST INDEX

After the base year parameters were determined and the MCI values were developed for each of the four sub-category indexes and for the composite index, the basket of goods was finalized. The amount of work activities included in the basket of goods was reduced from 33 to 12. Next an MCI spreadsheet tool was developed and data from 2012, 2013, and 2015 was used as examples.

## 5.1 Calculating the Base Year Parameters

Two base year parameters were calculated for the Laspeyres index from the individual work task data provided by the NCDOT. The first was a representative unit cost and the second was a representative quantity for each work activity in the base year. The most recent data provided at the time of development was 2014, making it the base year for the index.

To calculate the representative unit cost, it was first necessary to determine which work task records contained the data needed. For example, there were some work task records that had a total quantity but no cost associated with them and vice versa. The only work orders used when calculating the representative unit cost were the ones that had both a total cost and quantity associated with them.

Two different methods were considered for calculating a representative unit cost, including the average and median values. The unit cost data was not normally distributed therefore the average was not a good representative of all the unit costs. The median value was determined to be the best because it represented all the unit cost values. This can be seen in Figure 7 which shows the unit cost data for activity "2912-Brush & Tree Control/Mechanical/Other". This figure demonstrates how the average unit cost is far from the 50th percentile of the data, and why the median is a better representation of all the work orders. The median value falls within the unit costs that occur much more frequently for the work activity.

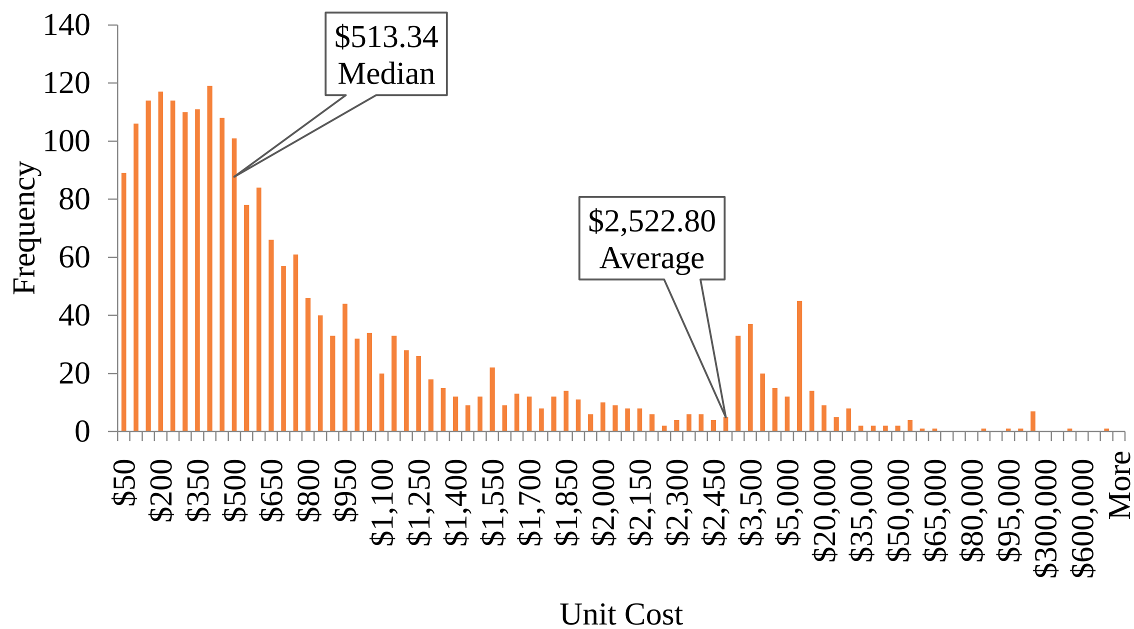


FIGURE 7: Unit cost data for 2912-Brush & tree control/mechanical/other

The second base year parameter was the total quantity of each activity in the base year. The quantity of each activity was calculated using the work task data provided by the NCDOT. There were outliers in the data that caused the quantity for some activities to be much larger than it actually was. A method to effectively remove these outliers without affecting the accuracy of the index was developed. A threshold quantity for individual work task records was established as the 98th percentile of the distribution of quantities recorded for each activity. Records with quantities over this threshold were neglected.

The bottom two percent of the quantity work orders were not eliminated in this process because the smaller quantities could not be clearly identified as outliers. For example, when the activity is measured by the shoulder mile a quantity of 8,000,000 shoulder miles for one record is clearly an outlier, but a recording of 0.1 shoulder miles may be accurate. After the top two percent of outliers were eliminated, the total quantity for each work order that had a quantity and cost associated with it was summed up.

For records where cost was recorded but not quantity, the quantity was estimated based on the median unit cost. This was done by calculating the total amount of money spent on each work activity where the quantity was either zero or no value was recorded. That amount of money was divided by the representative unit cost found previously. This was done because it produced an accurate base year quantity. It was important to calculate an accurate representative quantity because this was one of the two base year parameters, if this value was wrong then it would throw off the accuracy of the tool. By estimating the total quantity it was possible to account for the work orders that were performed without a quantity recorded. This was done for the 33 work activities included in the basket of goods.

After the estimated quantity was calculated for each work activity, the total sum of the recorded quantity was added to the estimated quantity. This provided the overall total quantity for each activity in the base year. Equation 5 is the formula used when calculating the total quantity and Figure 8 shows the number and percentage of the recorded quantity compared to the estimated quantity. As seen in Figure 8 the majority of the total quantity is based on the recorded data and not the estimated value.

$$Q_T = Q_C + \frac{C_{NQ}}{UC}$$ Equation 5

Where: $Q_T = Total\ estimated\ quantity$

$Q_C = Recorded\ quantity\ with\ cost$

$C_{NQ} = Cost\ without\ quantity\ recorded$

$UC = Median\ unit\ cost$

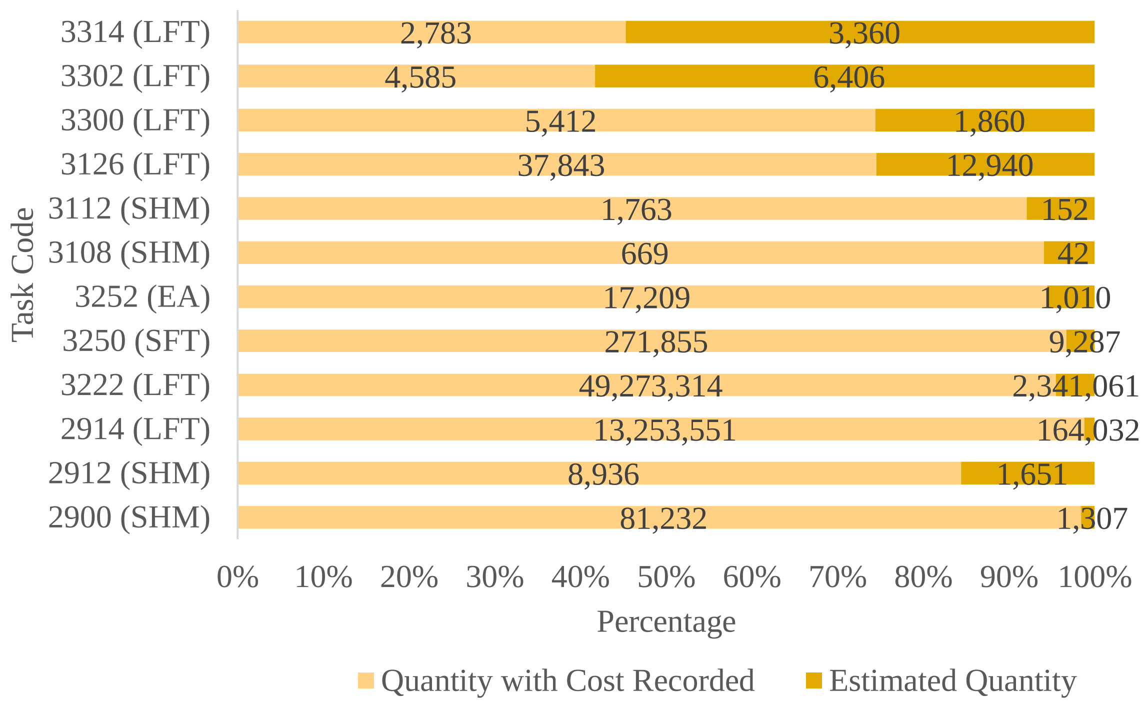


FIGURE 8: Percent of quantity recorded vs. estimated quantity in 2014

Table 3 shows an example of the two different base year parameters that were calculated for each work activity included in traffic category basket of goods. The base year parameters were used in the cost index formula in order to develop the MCI spreadsheet tool. These base year parameters are constant and will not change from year to year. The remaining base year parameters for the basket of goods can be found in Appendix D.

TABLE 3: 2014 Base year Laspeyres index parameters for roadside data

| **Index** | **Work Task** | **Unit** | **Median Unit Cost** | **Estimated Total Quantity** |
|---|---|---|---|---|
| **Roadside** | 2900-Grass Mowing | SHM | $73.29 | 137,786 |
| | 2904-Turf Management | ACR | $32.64 | 13,060 |
| | 2908-Brush and Tree Control /Herbicides | SHM | $151.19 | 2,066 |
| | 2912-Brush and Tree Control / Mechanical/ Other | SHM | $530.39 | 15,456 |
| | 2914-Vegetation Management at Stationary Objects | LFT | $0.38 | 22,466,658 |
| | 2916-Roadside Vegetation Enhancement | SYD | $0.19 | 11,283,315 |
| | 2918-Seeding and Mulching and Fertilization | ACR | $1,845.78 | 830 |

## 5.2 Calculating the MCI Values

The next task that was completed was calculating the MCI values. The Laspeyres index was used to calculate the MCI values. The base year parameter values calculated previously were used as the base year inputs for the Laspeyres index formula. These input values included the representative unit cost for each activity and the representative quantity for each activity during the base year of 2014.

The third value needed for the Laspeyres index formula was the current year unit cost. The current year unit cost is what determines how much the index fluctuates from year to year. The current year unit cost for each activity is calculated on a year to year basis through the MCI tool. This was calculated the same way the base year unit cost was calculated. The current year unit cost was determined using the median value for each work activity in the basket of goods. Examples of these values can be found in Table 16, which includes all the calculations for the cost indexes.

To calculate the MCI values the Laspeyres formula was used, this formula is calculated as follows:

$$I_{Lt} = 100 * \frac{\sum_{j=1}^{n} p_{jt} q_{j0}}{\sum_{j=1}^{n} p_{j0} q_{j0}} \qquad \text{Equation 6}$$

Where: $I_{Lt}$ = Laspeyres cost index in year $t$

$p_{jt}$ = price of good $j$ in year $t$

$p_{j0}$ = price of good $j$ in the base year 0

$q_{j0}$ = quantity of good $j$ in the base year 0

Each of these MCI values was calculated using the work activities associated with each categories basket of goods determined previously. One overall composite MCI was developed to combine the four sub-category indexes into one. This was done for simplicity of calculating one main MCI each year. All 33 work activities included in the basket of goods were used to calculate the composite MCI value. This MCI value was calculated the same as the sub-category indices. Using these 33 work activities the MCI tool produced an accurate value that represented all the work activities performed under the standing maintenance budget.

The resulting cost index value can be used to track past and forecast future costs for all standing maintenance activities performed by the NCDOT. Being able to track these costs will allow the NCDOT to budget for the upcoming years. Using the data from 2012 to 2015 provided by the NCDOT, an example spreadsheet was created to show which values to use and how to use them in order to calculate the different cost indices.

The tables and graphs for each of the four sub-categories and the composite MCI are presented in Figures 9 through 13 and Tables 4 through 8. These MCI values were calculated using all 33 activities in the basket of goods.

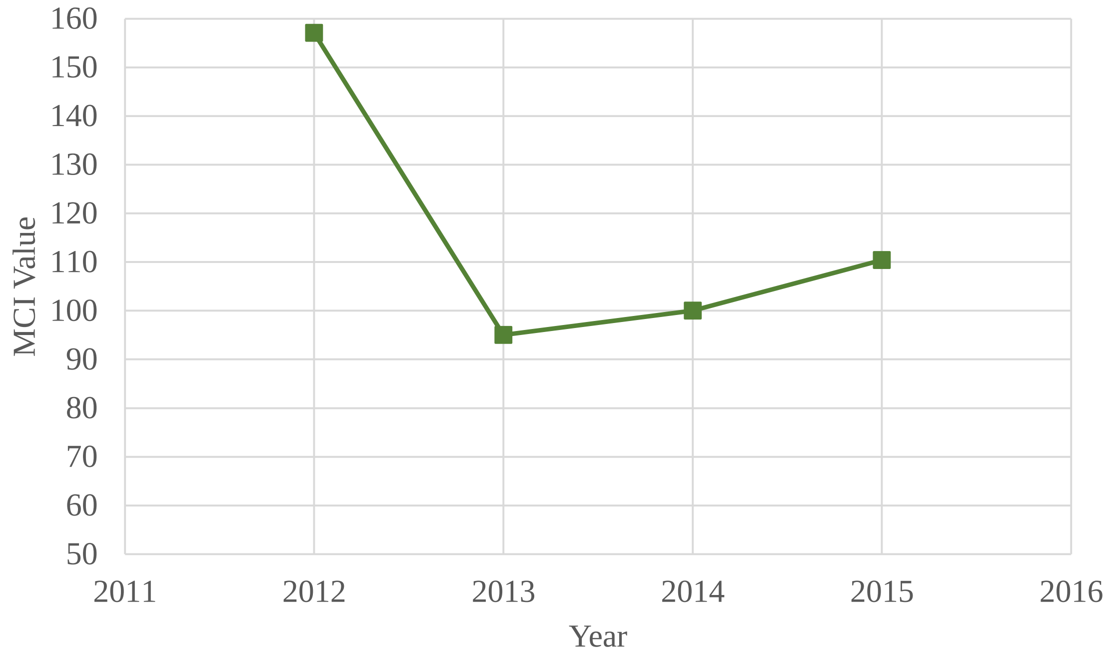


FIGURE 9: Tier 1-3 Roadside MCI values

TABLE 4: Tier 1-3 Roadside MCI values

| Roadside | |
|---|---|
| **Year** | **MCI Value** |
| 2012 | 157.1 |
| 2013 | 95 |
| 2014 | 100 |
| 2015 | 110.4 |

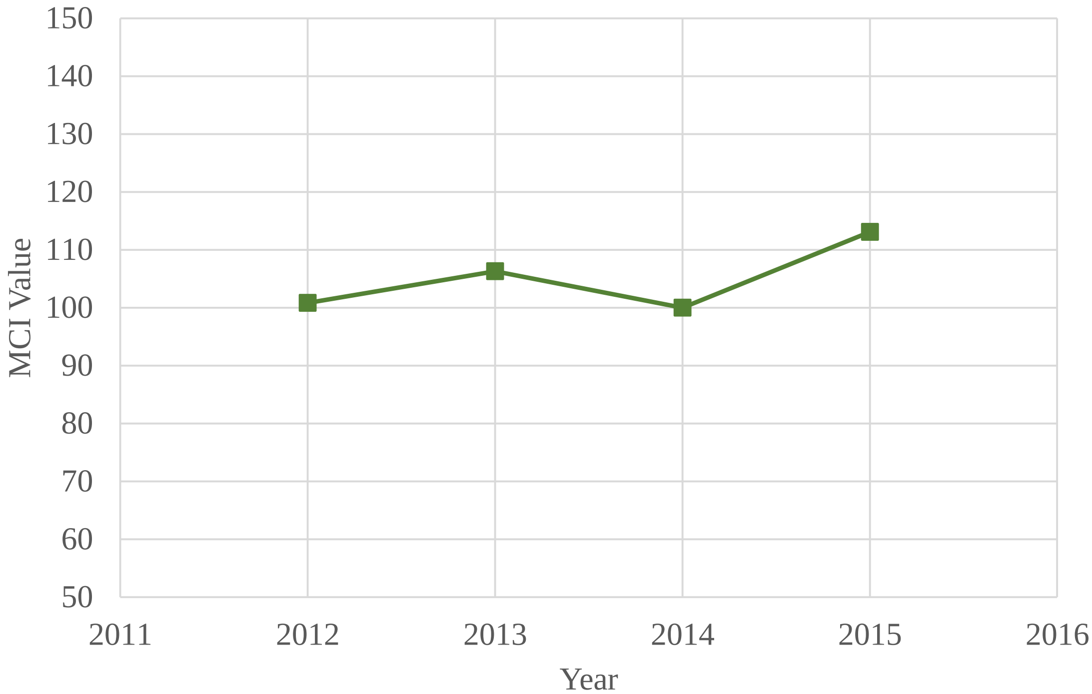


FIGURE 10: Tier 1-3 Traffic MCI values

TABLE 5: Tier 1-3 Traffic MCI values

| Traffic | |
|---|---|
| **Year** | **MCI Value** |
| 2012 | 100.8 |
| 2013 | 106.3 |
| 2014 | 100 |
| 2015 | 113.1 |

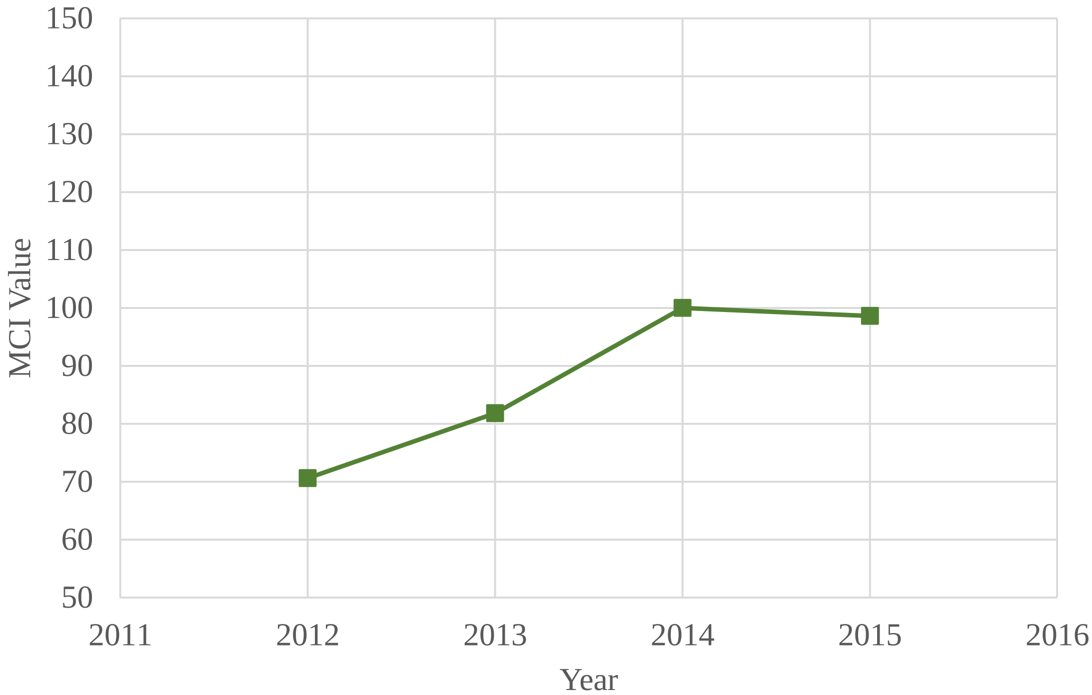


FIGURE 11: Tiers 1-3 Maintenance MCI values

TABLE 6: Tiers 1-3 Maintenance MCI values

| **Maintenance** | |
|---|---|
| **Year** | **MCI Value** |
| 2012 | 70.6 |
| 2013 | 81.8 |
| 2014 | 100 |
| 2015 | 98.6 |

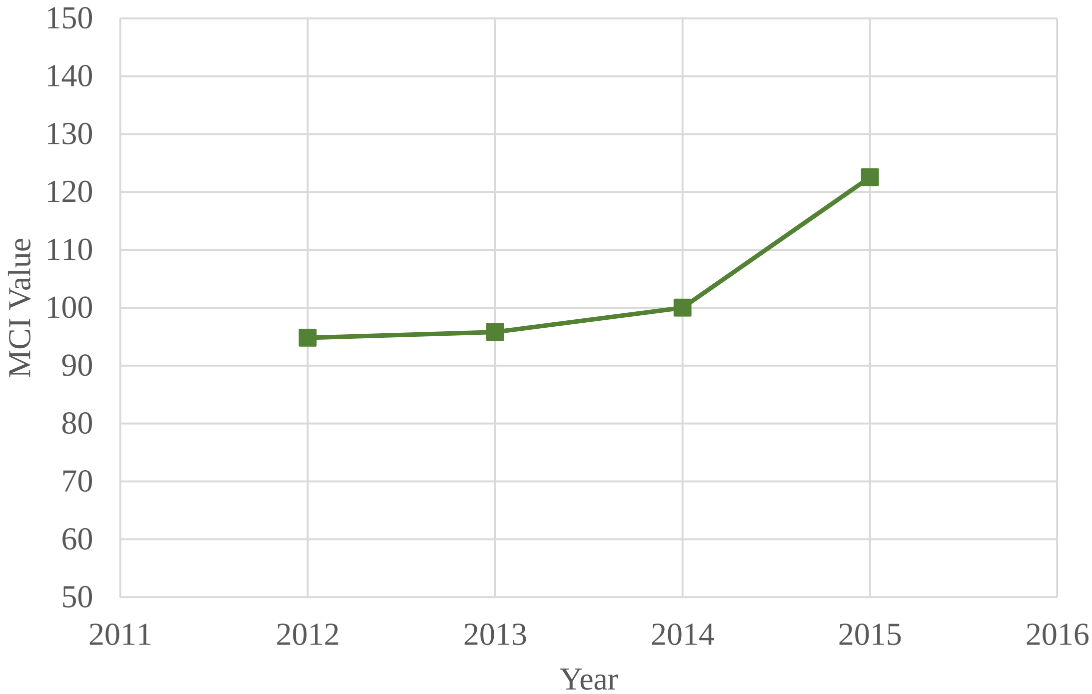


FIGURE 12: Tiers 1-3 Bridge MCI values

TABLE 7: Tiers 1-3 Bridge MCI values

| **Bridge** | |
|---|---|
| **Year** | **MCI Value** |
| 2012 | 94.8 |
| 2013 | 95.8 |
| 2014 | 100 |
| 2015 | 122.5 |

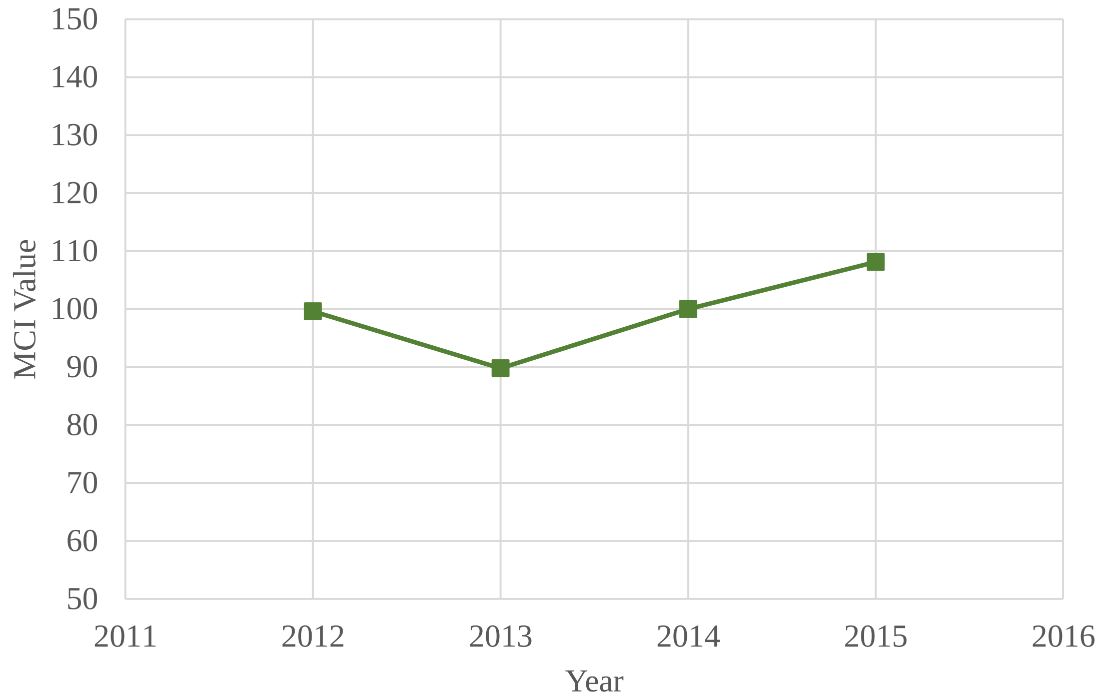


FIGURE 13: Tiers 1-3 Composite MCI values

TABLE 8: Tiers 1-3 Composite MCI values

| **Estimated Total** | |
|---|---|
| **Year** | **MCI Value** |
| 2012 | 99.6 |
| 2013 | 89.8 |
| 2014 | 100 |
| 2015 | 108.1 |

## 5.3 Assessment of the Basket of Goods

After calculating the MCI values with 33 activities in the basket of goods, the basket of goods was re-evaluated to determine if that number could be reduced. This allowed the MCI tool to use minimum data requirements and maintain its accuracy. It was determined that each sub-category needed enough work activities to accurately represent the whole and not be overly dependent on a single activity. Each sub-category was divided into three tiers based on 2014 annual work task recorded expenditures. Table 9 shows the three cost tiers for roadside work activities. The three tiers were determined based on the natural breaks in recorded cost. The other three tables created to determine the tiers for each sub-category can be found in Appendix E.

TABLE 9: Roadside work task tiered by total recorded work task expenditures

| Index | Work Task | 2014 |
|---|---|---|
| Roadside | 2912-Brush and Tree Control / Mechanical/ Other | $6,567,573 |
| | 2900-Grass Mowing | $5,199,471 |
| | 2914-Vegetation Management at Stationary Objects | $2,176,493 |
| | 2916-Roadside Vegetation Enhancement | $1,514,526 |
| | 2918-Seeding and Mulching and Fertilization | $1,295,128 |
| | 2904-Turf Management | $578,958 |
| | 2908-Brush and Tree Control /Herbicides | $420,054 |

Tier 1

Tier 2

Tier 3

It was possible to omit the work activities in tiers two and three from the calculations and still produce accurate and consistent MCI values. Table 10 shows the total amount of money spent on each sub-category in 2014, the amount of money spent when all three tiers were included, when tiers one and two were included, and when just tier one was included. As seen in Table 10 tier one activities in the traffic and roadside categories contained 84 percent and 77 percent of the total costs, respectively. The basket of goods for these categories consisted of three work activities each, accounting for a significant amount of the total money spent. The basket of goods for the maintenance and bridge categories did not account for as much of the total costs due to the fact that these two categories consisted of a significant amount of work activities. Tier one activities accounted for 64 percent and 50 percent of the total costs for the maintenance and bridge categories, respectively.

TABLE 10: 2014 Sub-category tier costs

| Index | Total Cost | Tiers 1-3 Cost | Percent of Total Cost | Tiers 1-2 Cost | Percent of Total Cost | Tier 1 Cost | Percent of Total Cost |
|---|---|---|---|---|---|---|---|
| Roadside | $18,131,548 | $17,752,202 | 98% | $16,753,191 | 92% | $13,943,537 | 77% |
| Traffic | $6,060,591 | $5,942,203 | 98% | $5,738,413 | 95% | $5,086,964 | 84% |
| Maintenance | $37,526,406 | $36,664,211 | 98% | $35,212,298 | 94% | $24,146,407 | 64% |
| Bridge | $22,209,918 | $16,383,830 | 74% | $13,171,464 | 59% | $11,108,144 | 50% |

The number of work activities that could be eliminated without affecting the accuracy of the overall MCI tool was determined after each of the four sub-categories were divided into three tiers. The MCI values were calculated, recorded, and graphed when all three of the tiers were included in the calculations (or all 33 work activities were included). Next the third tier of work tasks were omitted from the calculations, (leaving a total of 23 work activities) and these MCI values were recorded and graphed. The recorded values were compared side by side to determine if the values were consistent. It was determined that the MCI tool was still producing accurate and consistent values using just 23 work activities. The second tier of work activities were omitted from the calculations leaving just 12. These values were recorded and graphed. The values were analyzed by comparing them to the original MCI values calculated using all 33 work activities.

After the basket of goods was finalized each of the sub-category indices was calculated using the three activities associated with it. Also the composite MCI value was calculated using the 12 work activities which accounted for the four sub-categories basket of goods. These values were calculated the same way as presented previously. The only difference in the calculations is the number of activities in the basket of goods.

This process completed the basket of goods, which included 12 work activities. This included three work activities from each of the four sub-categories. These 12 work activities represent all the maintenance work activities in the standing maintenance budget completed in house by the NCDOT in a given year. Ultimately this decreased the original amount of work activities from 110 to 12. Combining the four sub-category indexes into one overall composite MCI makes it easier for the user to see the overall change in price from one year to the next.

Figures 14 through 18 and Tables 11 through 15 show the consistency of the MCI tool based on the second elimination process for the total basket of goods. The orange line labeled as tiers 1-3 is representative of when all 33 work tasks were included in the calculations. The blue line labeled tiers 1-2 represents when the third tier was omitted from the calculations and just 23 work tasks remained. Lastly the gray line labeled tier 1 represents when the second and third tiers were eliminated from the calculations leaving just 12 work activities. All of the MCI values kept the same shape throughout the elimination process and two of them varied in value a significant amount.

As seen in Figure 14 the roadside MCI values kept the same shape throughout the elimination process and showed little variation in value.

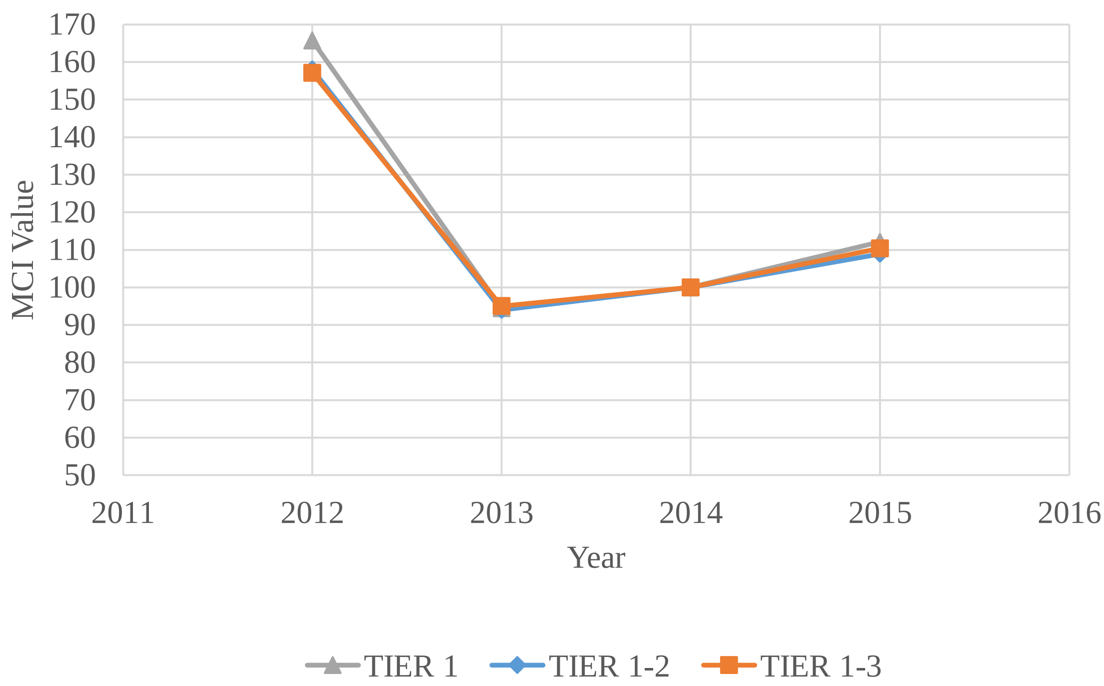


FIGURE 14: Roadside MCI values from 2012 to 2015

TABLE 11: Roadside MCI values from 2012 to 2015

| | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| Tiers 1-3 | 157.1 | 95 | 100 | 110.4 |
| Tiers 1-2 | 158 | 94 | 100 | 108.9 |
| Tier 1 | 165.7 | 94.4 | 100 | 112.1 |

Figure 15 shows that the traffic MCI values kept the same shape throughout the tier elimination process and showed little variation in value for years 2012 and 2015. In 2013 activity "3226 Long Line Specialty Material Pavement Markings" had an unusually large median unit cost. This activity was included in tier two which is why the value is much smaller when just tier one activities were included. This proved it was possible to eliminate tiers two and three.

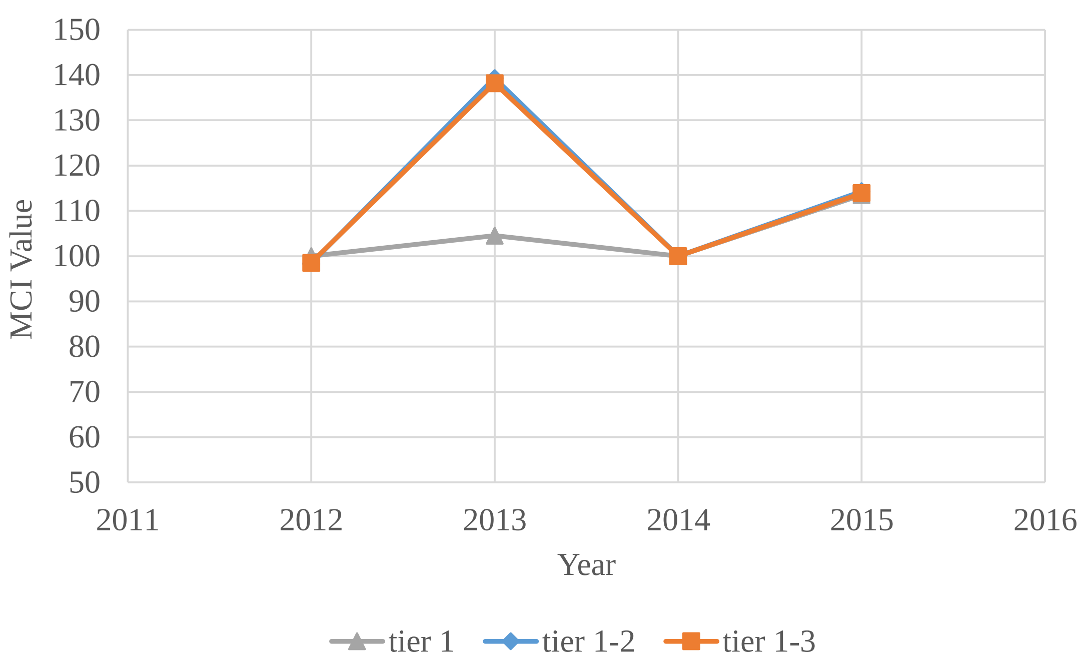


FIGURE 15: Traffic MCI values from 2012 to 2015

TABLE 12: Traffic MCI values from 2012 to 2015

| | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| Tiers 1-3 | 98.5 | 138.2 | 100 | 113.9 |
| Tiers 1-2 | 98.4 | 139.3 | 100 | 114.3 |
| Tier 1 | 100 | 104.5 | 100 | 113.5 |

Figure 16 shows that the maintenance MCI values kept the same shape and showed little variation in value throughout the elimination process. This proved it was possible to eliminate tiers two and three and still produce accurate and consistent values.

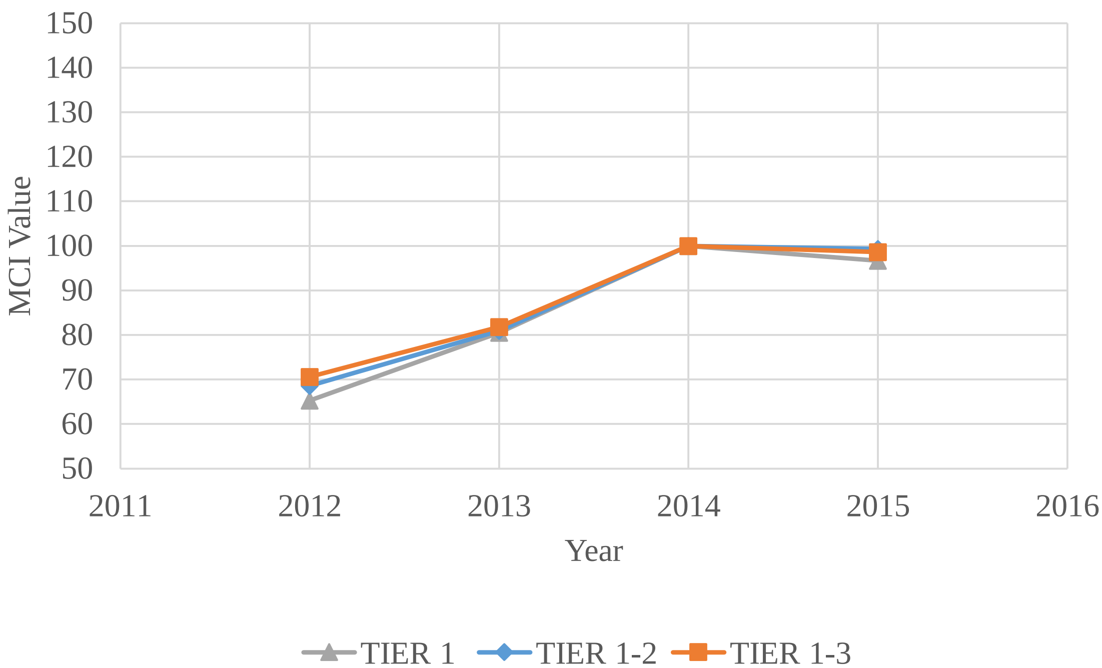


FIGURE 16: Maintenance MCI values from 2012 to 2015

TABLE 13: Maintenance MCI values from 2012 to 2015

| | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| Tiers 1-3 | 70.6 | 81.8 | 100 | 98.6 |
| Tiers 1-2 | 68.6 | 80.9 | 100 | 99.3 |
| Tier 1 | 65.3 | 80.5 | 100 | 96.7 |

Figure 17 shows the bridge MCI values kept the same shape for the most part and showed the largest variation in value in 2013. This variation in value was due to one work activity included in the second and third tiers that had extreme outliers.

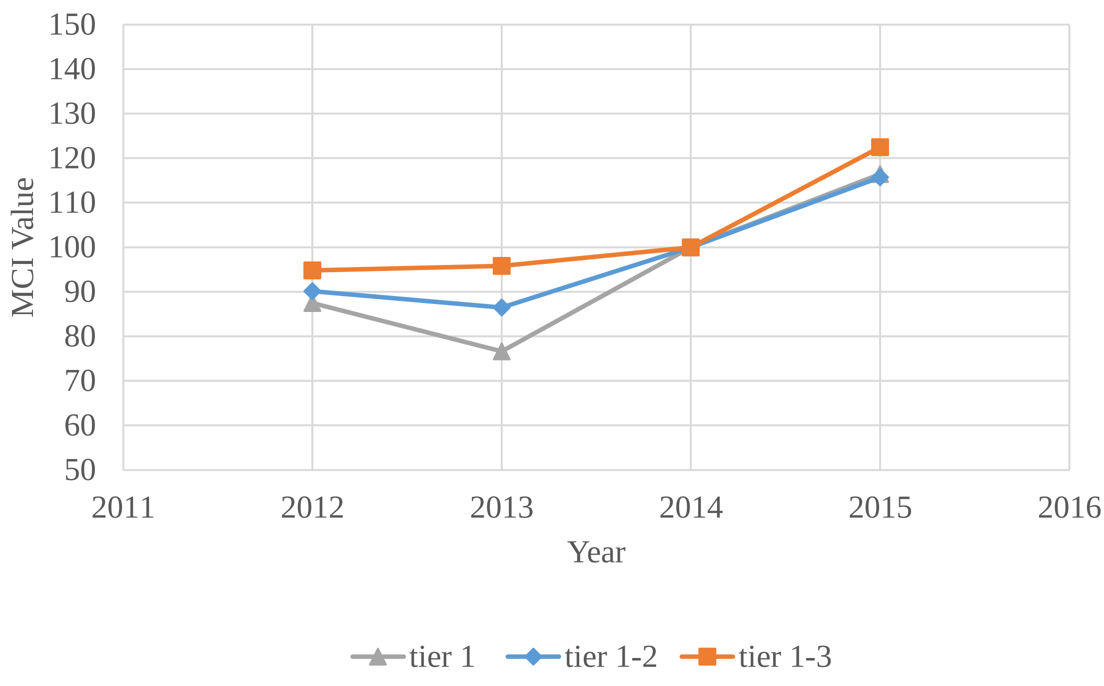


FIGURE 17: Bridge MCI values from 2012 to 2015

TABLE 14: Bridge MCI values from 2012 to 2015

| | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| Tiers 1-3 | 94.8 | 95.8 | 100 | 122.5 |
| Tiers 1-2 | 90.1 | 86.5 | 100 | 115.7 |
| Tier 1 | 87.5 | 76.6 | 100 | 116.4 |

Figure 18 shows the composite MCI values kept the same shape through the elimination process and had little variation in value. This proved it was possible to calculate an accurate MCI value using just 12 work activities for the basket of goods.

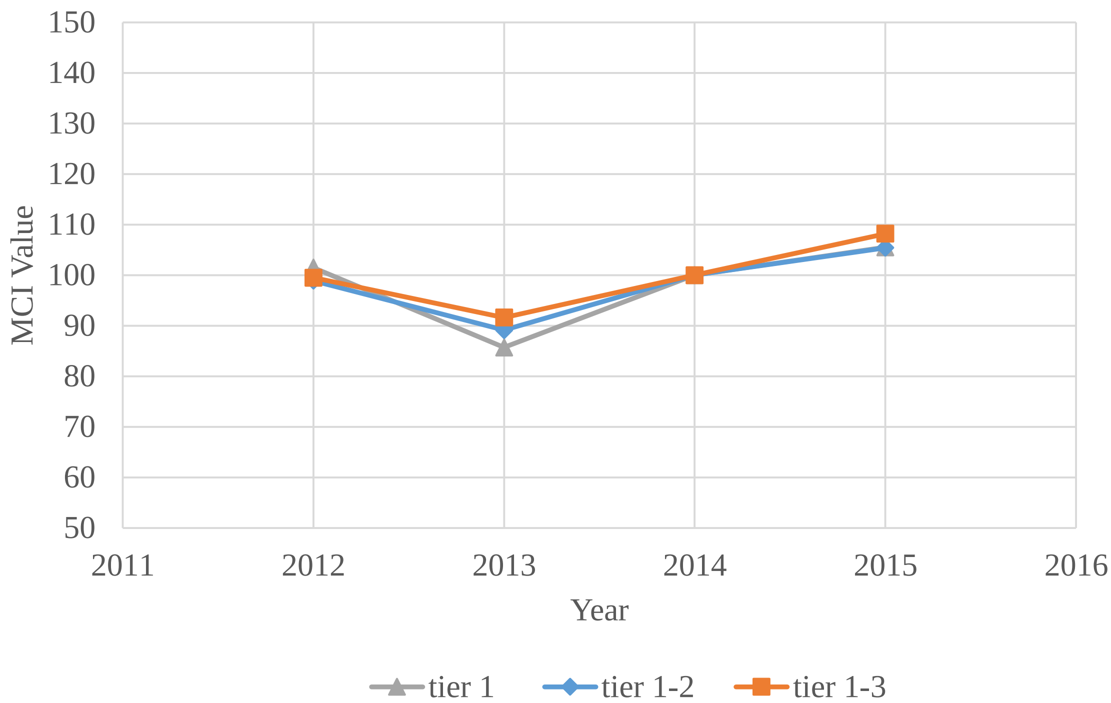


FIGURE 18: Composite MCI values from 2012 to 2015

TABLE 15: Composite MCI values from 2012 to 2015

| | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| Tiers 1-3 | 99.5 | 91.6 | 100 | 108.2 |
| Tiers 1-2 | 98.9 | 89.1 | 100 | 105.4 |
| Tier 1 | 101.5 | 85.7 | 100 | 105.5 |

## 5.4 Creating the MCI Tool

An MCI spreadsheet tool was created to calculate and track the approximate change in cost of the work activities over a three to five year period. The MCI tool allows for the NCDOT to use the data they already keep track of. They will not need to change their methods of recording data. The user will copy and paste the recorded data into the tool and the tool will calculate the MCI values. With the implementation of the MCI tool, the NCDOT will be able to better track and budget for future maintenance costs in an easy and timely manner. The work activities determined for the basket of goods and the base year parameters found previously were used when calculating the MCI values in the tool.

The MCI tool is composed of one workbook with seven different worksheets in it. These seven worksheets are labeled as follows:

1. Main Title page
2. Instructions
3. Raw Data
4. Base Year Parameters
5. Calculations
6. Results
7. MCI Values

The instructions worksheet gives the user brief instructions needed to use the tool correctly and efficiently. The raw data page is for the user to input the raw data on a year to year basis. This page allows the NCDOT to input all the data they already collect and record. The tool will sort out what is necessary to calculate the MCI values from the raw data. This makes it more user friendly so the NCDOT does not have to sort out the data or change the way they record data before inputting it into the tool.

The base year parameter worksheet contains all the base year parameters for the selected basket of goods that were previously calculated. Due to the fact that the base year parameters do not change this sheet will always remain the same and keep the same values. The calculation page is where all the current year parameters are calculated. This page will allow the user to see several different things such as the:

1. Quantity of tasks performed that year
2. Current year median unit cost
3. Current year recorded quantity
4. Current year estimated quantity
5. Current year total quantity
6. Other pieces of information found in Table 16

Table 16 shows an example of the information that is calculated and provided on the calculations tab of the spreadsheet tool. Also on this page, as seen in Table 16, is a column labeled “Threshold”. This is where the $98^{th}$ percentile is calculated for the quantities of each activity as explained before. This determines which individual work tasks should be included and which ones should be left out of the calculations. If the quantity of an individual work task is larger than the threshold amount, that individual work task is not included in the rest of the calculations. As stated before this is also something that the MCI tool does automatically to make it more user friendly.

TABLE 16: Summary of current year data provided

| Index | Work Task | Unit | Task | Fiscal Year | Threshold | No. of Work Task Records | | | | Total Work Order Cost | Median Unit Cost | Total Quantity (qty w/ cost) | Estimated Quantity (based on cost) | Estimated Total Quantity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total | Quantity & Cost | Quantity Only | Cost Only | | | | | |
| Roadside | 2900-Grass Mowing | SHM | 2900 | 2014 | 7,199 | 355 | 311 | 22 | 22 | $ 5,199,471 | $ 73.29 | 136,414 | 1,372 | 137,786 |
| | 2912-Brush and Tree Control / Mechanical/ Other | SHM | 2912 | 2014 | 124 | 2,350 | 2,191 | 50 | 107 | $ 6,567,573 | $ 530.39 | 13,747 | 1,709 | 15,456 |
| | 2914-Vegetation Management at Stationary Objects | LFT | 2914 | 2014 | 525,017 | 906 | 808 | 5 | 93 | $ 2,176,493 | $ 0.38 | 22,289,676 | 176,982 | 22,466,658 |
| Traffic | 3222-Long Line Painted Pavement Markings | LFT | 3222 | 2014 | 205,314 | 1,454 | 1,373 | 47 | 34 | $ 2,223,728 | $ 0.04 | 56,231,283 | 2,341,061 | 58,572,344 |
| | 3250-Install / Replace Ground Mounted Signs | SFT | 3250 | 2014 | 427 | 6,018 | 5,891 | 13 | 111 | $ 1,986,384 | $ 8.03 | 333,929 | 9,460 | 343,389 |
| | 3252-Repair Ground Mounted Signs | EA | 3252 | 2014 | 37 | 5,098 | 4,981 | 3 | 114 | $ 876,852 | $ 41.04 | 21,342 | 1,025 | 22,367 |
| Maintenance | 3108-Drainage Ditch Maintenance | SHM | 3108 | 2014 | 5 | 3,518 | 3,277 | 2 | 238 | $ 9,097,899 | $ 17,711.33 | 961 | 44 | 1,005 |
| | 3112-Shoulder Maintenance / Reconstruction | SHM | 3112 | 2014 | 12 | 2,624 | 2,330 | 45 | 191 | $ 9,062,249 | $ 7,626.54 | 2,436 | 161 | 2,597 |
| | 3126-Install Pipes (<=48") | LFT | 3126 | 2014 | 144 | 1,361 | 1,198 | 8 | 151 | $ 5,986,258 | $ 83.15 | 41,858 | 12,931 | 54,789 |
| Bridge | 3300-Install / Replace NON NBIS > 48" up to NBIS Structures | LFT | 3300 | 2014 | 1,556 | 95 | 79 | 3 | 13 | $ 8,162,600 | $ 1,093.88 | 7,609 | 1,970 | 9,578 |
| | 3302-Maintain / Repair NON NBIS > 48" up to NBIS Structures | LFT | 3302 | 2014 | 424 | 112 | 92 | 1 | 19 | $ 1,630,306 | $ 124.14 | 5,596 | 6,443 | 12,039 |
| | 3314-Maintain Steel Superstructure Components | LFT | 3314 | 2014 | 612 | 105 | 73 | 2 | 30 | $ 1,315,239 | $ 223.03 | 3,456 | 3,772 | 7,228 |

The results page calculates the numerator and denominator needed for the MCI values. This includes the current year unit price multiplied by the base year quantity and the base year quantity multiplied by the base year unit price. Both of these calculations are completed on this page for the work activities included in the basket of goods. This allows the user to visualize which activities have increased or decreased in price compared to the base year price. Also on this page is a table with the total sums of the above two products for each of the sub-categories and for all the work activities included in the basket of goods. This allows the user to see exactly how much the sum of money spent has increased or decreased from the base year for each of the five indexes.

The MCI values page provides the user with the MCI values of the current year for each of the four sub-categories and the overall composite MCI. Also on this page are five tables for the user to update each year by inputting the current years MCI value found at the top of the worksheet. Through these tables a graph will be plotted for each of the four sub-categories and for the overall composite MCI. This allows the user to better visualize and track the changes in costs from year to year. These graphs will plot automatically once the user inputs the MCI values for the current year. Years 2012 to 2015 have already been input and graphed as an example.

# CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This research consisted of developing a more efficient and accurate way to estimate future highway maintenance costs for the NCDOT. Five MCIs specific to highway maintenance costs were developed. A spreadsheet tool was developed to calculate these MCI values annually. The tool allows for the NCDOT to estimate future highway maintenance costs, using the data they currently keep track of and record. Due to the fact that the data used was from NCDOT maintenance, the values should only be used by the NCDOT and not other DOTs. However the methodology can be used by other DOTs to develop MCIs based on their data.

## 6.1 Conclusions

1. The Laspeyres index formula was used to develop the MCI values because it is based on the change in cost from year to year and not the quantity. Also the basket of goods is not expected to change from year to year due to the fact that the same maintenance activities will continue to be performed for highway maintenance.
2. The existing data that is collected supports the development of the cost index. Therefore, the need to collect new data or change the current ways of collecting data is not necessary.
3. Narrowing down the basket of goods from 110 activities to 12, allows for less data requirements. This also made the tool more accurate because it eliminated the activities that had inaccurate and skewed data. Too many activities makes the tool inefficient.

4. Calculating four different sub-category MCI values allows the NCDOT to analyze each sub-category separately. This will allow them to determine which type of maintenance activities are affecting the MCI the most from year to year. The overall MCI value will allow the user to analyze and track the costs for the entire standing maintenance budget.
5. Maintenance costs vary from year to year making the MCI values useful for the user. The MCI values will allow the user to better track past costs and forecast future costs specific to highway maintenance.

## 6.2 Recommendations

The following recommendations were made based on the results and conclusions drawn from the research conducted.

1. When calculating the representative unit cost for the index formula the median value was determined to be the best representative of all the work orders. This was because the unit cost data was not normally distributed causing the average unit cost to be much larger than the median value. On the other hand, the median value was where the highest frequency of work orders were.
2. When calculating the total quantity for each work activity it was determined that the top two percent would be eliminated. This was because the top two percent were clearly extreme outliers that skewed the data. It was important to get the most accurate values for the base year parameters because these were the values that the cost index was based on. The bottom two percent of the data was not eliminated because there was not a clear way to determine which of the bottom two percent were outliers.

3. Due to the fact that maintenance costs vary from year to year the index should be used to track past costs and forecast future costs. This will allow for more accurate budgeting and planning.
4. Data specific to maintenance activities should continue to be carefully collected and recorded while focusing on capturing all task parameters. The NCDOT should focus on the quality of the data specifically the quantity and total cost performed. The indices should be re-evaluated in three to five years if the data records become more accurate. The base year should be updated if the data becomes more accurate in order to allow for more accurate future MCI values. This will allow for a more accurate MCI tool to be created. The same methodology used for the developed MCI values should be used when doing this.
5. The basket of goods for the index should be periodically reviewed to make sure the top expenditures are not different for an extended amount of time. The top expenditures may vary on a year to year basis but they should not be changed or updated unless a consistent change of approximately three years or more is noticed.

## 6.3 Future Work

Moving forward the developed MCI methodology could be used to create MCI values on a national level. If this were to be done the basket of goods would need to be decided based on all the states involved. The basket of goods would have to include work activities from every state in order to be useful for all states. This could also be broken down by regions that perform similar maintenance work activities. This would allow the basket of goods to be more specific to each state in the given region. This is due to the fact that not all state DOTs perform the same maintenance activities.

As stated before the created indices are specific to maintenance work performed by the NCDOT therefore, they should only be used by the NCDOT.  If other state DOTs want to create MCIs based on their maintenance work the above methodology can be used for data collected that is specific to their maintenance work.

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APPENDIX A: 2014 TOTAL COSTS OF WORK ACTIVITIES

| Work Activity | 2014 | |
|---|---|---|
| | **Total Cost** | **Percent of Total Cost** |
| **Roadside** | | |
| 2900-Grass Mowing | $25,095,789 | 32% |
| 2920-Rest Areas & Welcome Centers Operations | $12,767,633 | 16% |
| 2912-Brush and Tree Control / Mechanical/ Other | $15,448,688 | 20% |
| 2909-Manual Brush and Tree Control | $7,425,264 | 10% |
| 2916-Roadside Vegetation Enhancement | $5,187,622 | 7% |
| 2914-Vegetation Management at Stationary Objects | $5,082,336 | 7% |
| 2918-Seeding and Mulching and Fertilization | $3,641,694 | 5% |
| 2904-Turf Management | $1,612,259 | 2% |
| 2908-Brush and Tree Control /Herbicides | $1,058,670 | 1% |
| 2924-NPDES Mntc and Installation of Strmwtr BMPs | $437,033 | 1% |
| 2906-Control of Invasive Species | $242,229 | 0% |
| 2926-Maint of Strmwtr BMPs | $102,205 | 0% |
| 2907-Control of Aquatic Species (NPDES Compliance) | $17,557 | 0% |
| 2922-BMP Retrofits | $1,391 | 0% |
| 2902-Appln Fees Vege Removal | $662 | 0% |
| **Maintenance** | | |
| 3102-Removal of Hazards/Debris From ROW | $20,670,395 | 19% |
| 3112-Shoulder Maintenance / Reconstruction | $19,150,893 | 18% |
| 3108-Drainage Ditch Maintenance | $18,001,571 | 16% |
| 3126-Install Pipes (<=48") | $10,244,311 | 9% |
| 3128-Maint/Repair Pipes (<=48") | $6,884,690 | 6% |
| 3130-Install/Maintain/Repair of Misc. Drainage Structures | $6,072,289 | 6% |
| 3140-Unpaved Road Stabilization Surface Maintenance | $4,949,620 | 5% |
| 3138-Machining Unpaved Road | $4,307,395 | 4% |
| 3104-Litter Removal | $4,072,549 | 4% |
| 3109-Major Maintenance of Shoulders and Ditches | $3,587,559 | 3% |
| 3127-Install Driveway Pipe | $2,707,953 | 2% |
| 3106-Bagged Litter and Trash Can Pickup | $1,956,745 | 2% |
| 3132-Sweep / Wash Roadway | $1,586,289 | 1% |
| 3134-Roadway Grading | $1,521,474 | 1% |
| 3103-Removal of Sand from the ROW | $999,357 | 1% |

| | | |
|---|---|---|
| 3120-Repair / Maintain Barriers | $972,794 | 1% |
| 3110-Beaver Control | $554,491 | 1% |
| 3136-Roadway Base Construction | $384,698 | 0% |
| 3124-Install/Repair/Replace Roadway Fences | $288,161 | 0% |
| 3100-Snow and Ice | $270,296 | 0% |
| 3107-Graffiti Removal | $119,335 | 0% |
| 3118-Install Barriers | $99,865 | 0% |
| 3122-Maintenance Repair and Replacement of Attenuators | $90,269 | 0% |
| 3101-Anti-Icing | $33,789 | 0% |
| 3116-Maintenance of Truck Escape Ramps | $33,139 | 0% |
| 3105-Removal/Disposal of hanging and leaning trees from ROW. | $1,033 | 0% |
| **Traffic** | | |
| 3250-Install / Replace Ground Mounted Signs | $8,882,353 | 25% |
| 3252-Repair Ground Mounted Signs | $6,039,481 | 17% |
| 3222-Long Line Painted Pavement Markings | $5,901,491 | 16% |
| 3240-Electricity for Traffic Control Devices | $5,721,539 | 16% |
| 3242-Roadway and Interchange Lighting | $1,698,220 | 5% |
| 3244-Temporary Traffic Control | $1,512,186 | 4% |
| 3230-Words and Symbols - Specialty Materials | $1,504,235 | 4% |
| 3226-Long Line Specialty Material Pavement Markings | $1,016,538 | 3% |
| 3200-Route Surv & Incid Detect & Response | $631,851 | 2% |
| 3238-Emergency Response to Traffic Signals | $631,698 | 2% |
| 3218-Curb and Gutter Installation and Repair. | $463,342 | 1% |
| 3232-Install / Replace Pavement Markers | $363,539 | 1% |
| 3236-Traffic Signal Routine Maintenance | $312,584 | 1% |
| 3214-Adopt-A-Highway Program | $223,264 | 1% |
| 3228-Words and Symbols - Painted | $204,811 | 1% |
| 3220-Preline | $160,430 | 0% |
| 3204-ITS Devices | $144,802 | 0% |
| 3224-Pavement Marking Removal | $105,460 | 0% |
| 3216-Channelization | $79,955 | 0% |
| 3256-Repair Overhead Signs | $79,218 | 0% |
| 3202-Changeable Message Sign | $58,635 | 0% |
| 3210-LOGO Sign Program | $34,620 | 0% |
| 3234-Installation / Upgrade of Traffic Signals | $31,815 | 0% |
| 3254-Install / Replace Overhead Signs | $17,989 | 0% |
| 3246-Computer Traffic Control System | $17,479 | 0% |
| 3201-Locating Traffic Signals and/or ITS Devices | $7,813 | 0% |

| | | |
|---|---|---|
| 3208-Junkyard Program | $1,183 | 0% |
| 3206-ODA (Outdoor Advertising) Program | $462 | 0% |
| 3212-TODS Sign Program | $254 | 0% |
| **Bridge** | | |
| 3300-Install / Replace NON NBIS > 48" up to NBIS Structures | $10,571,310 | 26% |
| 3310-Maintenance/Repair/Replacement of Standard Bridge Expansion Joints | $2,790,374 | 7% |
| 3302-Maintain / Repair NON NBIS > 48" up to NBIS Structures | $2,501,117 | 6% |
| 3314-Maintain Steel Superstructure Components | $2,335,555 | 6% |
| 3352-Maint Slope Protection | $2,044,628 | 5% |
| 3366-Drift and Debris Removal | $1,879,341 | 5% |
| 3376-Clean/Wash Bridge Decks | $1,813,106 | 4% |
| 3344-Repair / Replace Timber Substructure Components | $1,784,921 | 4% |
| 3368-Installation and Replacement of NBIS Pipes and Culverts | $1,666,048 | 4% |
| 3348-Maintain Concrete Substructure Components | $1,595,505 | 4% |
| 3372-Bridge Installation & Replacement | $1,523,460 | 4% |
| 3326-Maintain Concrete Deck | $1,210,660 | 3% |
| 3353-Maint or Repair of Concrete Bridge Approach Slab | $1,018,743 | 2% |
| 3338-Moveable Bridges (Operations) | $986,981 | 2% |
| 3324-Maint / Repair / Replace Timber Deck Components | $859,301 | 2% |
| 3346-Repair / Maintain Timber Wings & Blkhds | $734,185 | 2% |
| 3336-Moveable Bridges (Maintenance) | $636,937 | 2% |
| 3306-Maintain Concrete Superstructure Components | $626,786 | 2% |
| 3354-Maintain Steel Substructure Components | $552,709 | 1% |
| 3370-Maintenance and Repair of NBIS Pipes and Culverts | $499,608 | 1% |
| 3316-Maint to Timber Handrail | $493,004 | 1% |
| 3328-Maintenance/Repair/ Replace Steel Plank Bridge Floor | $464,132 | 1% |
| 3318-Maint to Concrete Handrail | $395,945 | 1% |
| 3342-Clean and Paint Structural Steel | $318,886 | 1% |
| 3322-Maint to Steel Handrail | $288,335 | 1% |
| 3334-Bridge Bearings | $257,212 | 1% |
| 3304-Maintain/Replace Timber Superstructure Components | $251,527 | 1% |
| 3350-Maint R C Wings and Walls | $232,975 | 1% |
| 3332-Maint Drainage System - Bridge | $224,904 | 1% |
| 3308-Maint. Of Steel Plate Bridge Joints | $209,419 | 1% |
| 3362-Maintenance and Repair of Fender System | $202,585 | 0% |

| | | |
|---|---|---|
| 3330-Maintenance/Repair Open Grid Steel Floor | $74,614 | 0% |
| 3320-Maint to Aluminum Handrail | $56,787 | 0% |
| 3358-Maintenance of Noise Walls | $37,176 | 0% |
| 3374-Repair and Maint of Pedestrian Bridges | $35,560 | 0% |
| 3312-Maint/Replace/Repair Modular Bridge Joints | $17,410 | 0% |
| 3360-Maintenance of Structural Walls & Tunnels | $9,256 | 0% |
| 3340-Maint Navigation Lights | $7,275 | 0% |
| 3371-Replace Bridge with Culvert | $2,360 | 0% |
| 3364-Replace / Construct Fender System | $1,304 | 0% |

APPENDIX B: NUMBER OF WORK ORDERS PER ACTIVITY

| Work Task | No. of Work Task Records in 2014 | | | |
|---|---|---|---|---|
| | Total | Quantity & Cost | Quantity Only | Cost Only |
| 2900-Grass Mowing | 413 | 317 | 22 | 22 |
| 2902-Appln Fees Vege Removal | 0 | 0 | 0 | 0 |
| 2904-Turf Management | 197 | 180 | 0 | 4 |
| 2906-Control of Invasive Species | 35 | 21 | 0 | 5 |
| 2907-Control of Aquatic Species (NPDES Compliance) | 0 | 0 | 0 | 0 |
| 2908-Brush and Tree Control /Herbicides | 383 | 93 | 0 | 5 |
| 2909-Manual Brush and Tree Control | 0 | 0 | 0 | 0 |
| 2912-Brush and Tree Control / Mechanical/ Other | 2,731 | 2,236 | 50 | 107 |
| 2914-Vegetation Management at Stationary Objects | 978 | 824 | 5 | 93 |
| 2916-Roadside Vegetation Enhancement | 130 | 110 | 0 | 1 |
| 2918-Seeding and Mulching and Fertilization | 670 | 541 | 0 | 30 |
| 2920-Rest Areas & Welcome Centers Operations | 16 | 12 | 0 | 0 |
| 2922-BMP Retrofits | 0 | 0 | 0 | 0 |
| 2924-NPDES Mntc and Installation of Storm water BMPs | 7 | 1 | 0 | 4 |
| 2926-Maint of Storm water BMPs | 20 | 18 | 0 | 0 |
| 3100-Snow and Ice | 10 | 6 | 0 | 1 |
| 3101-Anti-Icing | 0 | 0 | 0 | 0 |
| 3102-Removal of Hazards/Debris From ROW | 1,432 | 1,280 | 37 | 4 |
| 3103-Removal of Sand from the ROW | 0 | 0 | 0 | 0 |
| 3104-Litter Removal | 754 | 663 | 0 | 30 |

| | | | | |
|---|---|---|---|---|
| 3105-Removal / Disposal of hanging and leaning trees from ROW. | 0 | 0 | 0 | 0 |
| 3106-Bagged Litter and Trash Can Pickup | 694 | 627 | 5 | 19 |
| 3107-Graffiti Removal | 0 | 0 | 0 | 0 |
| 3108-Drainage Ditch Maintenance | 3,903 | 3,343 | 2 | 238 |
| 3109-Major Maintenance of Shoulders and Ditches | 0 | 0 | 0 | 0 |
| 3110-Beaver Control | 64 | 58 | 0 | 0 |
| 3112-Shoulder Maintenance / Reconstruction | 2,963 | 2,380 | 45 | 191 |
| 3116-Maintenance of Truck Escape Ramps | 14 | 12 | 0 | 0 |
| 3118-Install Barriers | 8 | 4 | 0 | 2 |
| 3120-Repair / Maintain Barriers | 195 | 155 | 1 | 7 |
| 3122-Maintenance Repair and Replacement of Attenuators | 7 | 3 | 1 | 1 |
| 3124-Install/Repair/Replace Roadway Fences | 80 | 64 | 0 | 5 |
| 3126-Install Pipes (<=48") | 1,572 | 1,222 | 8 | 151 |
| 3127-Install Driveway Pipe | 0 | 0 | 0 | 0 |
| 3128-Maint/Repair Pipes (<=48") | 2,169 | 1,731 | 4 | 177 |
| 3130-Install/ Maintain / Repair of Misc. Drainage Structures | 1,148 | 921 | 2 | 83 |
| 3132-Sweep / Wash Roadway | 150 | 125 | 0 | 15 |
| 3134-Roadway Grading | 74 | 71 | 0 | 0 |
| 3136-Roadway Base Construction | 23 | 13 | 1 | 4 |
| 3138-Machining Unpaved Road | 1,957 | 1,731 | 21 | 57 |
| 3140-Unpaved Road Stabilization Surface Maintenance | 1,024 | 789 | 10 | 117 |
| 3200-Route Surv & Incid Detect & Response | 314 | 293 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| 3201-Locating Traffic Signals and/or ITS Devices | 0 | 0 | 0 | 0 |
| 3202-Changeable Message Sign | 2 | 2 | 0 | 0 |
| 3204-ITS Devices | 3 | 3 | 0 | 0 |
| 3206-ODA (Outdoor Advertising) Program | 0 | 0 | 0 | 0 |
| 3208-Junkyard Program | 0 | 0 | 0 | 0 |
| 3210-LOGO Sign Program | 1 | 1 | 0 | 0 |
| 3212-TODS Sign Program | 0 | 0 | 0 | 0 |
| 3214-Adopt-A-Highway Program | 474 | 174 | 0 | 0 |
| 3216-Channelization | 30 | 26 | 0 | 2 |
| 3218-Curb and Gutter Installation and Repair. | 61 | 48 | 0 | 2 |
| 3220-Preline | 66 | 52 | 0 | 9 |
| 3222-Long Line Painted Pavement Markings | 1,560 | 1,402 | 47 | 34 |
| 3224-Pavement Marking Removal | 58 | 45 | 0 | 11 |
| 3226-Long Line Specialty Material Pavement Markings | 51 | 18 | 14 | 7 |
| 3228-Words and Symbols – Painted | 70 | 53 | 1 | 12 |
| 3230-Words and Symbols - Specialty Materials | 269 | 247 | 0 | 11 |
| 3232-Install / Replace Pavement Markers | 26 | 17 | 1 | 7 |
| 3234-Installation / Upgrade of Traffic Signals | 1 | 0 | 0 | 1 |
| 3236-Traffic Signal Routine Maintenance | 2 | 0 | 0 | 0 |
| 3238-Emergency Response to Traffic Signals | 11 | 10 | 0 | 0 |
| 3240-Electricity for Traffic Control Devices | 0 | 0 | 0 | 0 |
| 3242-Roadway and Interchange Lighting | 9 | 9 | 0 | 0 |
| 3244-Temporary Traffic Control | 288 | 276 | 1 | 2 |

| | | | | |
|---|---|---|---|---|
| 3246-Computer Traffic Control System | 0 | 0 | 0 | 0 |
| 3250-Install / Replace Ground Mounted Signs | 6,433 | 6,009 | 15 | 111 |
| 3252-Repair Ground Mounted Signs | 5,431 | 5,082 | 3 | 114 |
| 3254-Install / Replace Overhead Signs | 5 | 1 | 0 | 2 |
| 3256-Repair Overhead Signs | 7 | 4 | 0 | 3 |
| 3300-Install / Replace NON NBIS > 48" up to NBIS Structures | 122 | 80 | 3 | 13 |
| 3302-Maintain / Repair NON NBIS > 48" up to NBIS Structures | 156 | 93 | 1 | 19 |
| 3304-Maintain/Replace Timber Superstructure Components | 33 | 20 | 0 | 5 |
| 3306-Maintain Concrete Superstructure Components | 164 | 102 | 1 | 14 |
| 3308-Maint. Of Steel Plate Bridge Joints | 7 | 5 | 0 | 0 |
| 3310-Maintenance/Repair/Replacement of Standard Bridge Expansion Joints | 156 | 99 | 0 | 8 |
| 3312-Maint/Replace/Repair Modular Bridge Joints | 2 | 1 | 0 | 1 |
| 3314-Maintain Steel Superstructure Components | 154 | 74 | 2 | 30 |
| 3316-Maint to Timber Handrail | 121 | 77 | 0 | 11 |
| 3318-Maint to Concrete Handrail | 60 | 41 | 0 | 7 |
| 3320-Maint to Aluminum Handrail | 14 | 5 | 0 | 3 |
| 3322-Maint to Steel Handrail | 74 | 46 | 1 | 4 |
| 3324-Maint / Repair / Replace Timber Deck Components | 74 | 51 | 0 | 7 |
| 3326-Maintain Concrete Deck | 188 | 135 | 0 | 19 |
| 3328-Maintenance/Repair/ Replace Steel Plank Bridge Floor | 33 | 22 | 0 | 2 |
| 3330-Maintenance/Repair Open Grid Steel Floor | 5 | 4 | 0 | 1 |
| 3332-Maint Drainage System – Bridge | 38 | 25 | 0 | 2 |
| 3334-Bridge Bearings | 39 | 27 | 0 | 4 |

| | | | | |
|---|---|---|---|---|
| 3336-Moveable Bridges (Maintenance) | 6 | 5 | 0 | 1 |
| 3338-Moveable Bridges (Operations) | 4 | 4 | 0 | 0 |
| 3340-Maint Navigation Lights | 3 | 3 | 0 | 0 |
| 3342-Clean and Paint Structural Steel | 53 | 40 | 0 | 5 |
| 3344-Repair / Replace Timber Substructure Components | 143 | 97 | 0 | 15 |
| 3346-Repair / Maintain Timber Wings & Blkhds | 136 | 82 | 2 | 19 |
| 3348-Maintain Concrete Substructure Components | 151 | 101 | 0 | 21 |
| 3350-Maint R C Wings and Walls | 37 | 25 | 0 | 3 |
| 3352-Maint Slope Protection | 253 | 161 | 2 | 40 |
| 3353-Maint or Repair of Concrete Bridge Approach Slab | 0 | 0 | 0 | 0 |
| 3354-Maintain Steel Substructure Components | 18 | 11 | 0 | 3 |
| 3358-Maintenance of Noise Walls | 5 | 0 | 0 | 2 |
| 3360-Maintenance of Structural Walls & Tunnels | 1 | 1 | 0 | 0 |
| 3362-Maintenance and Repair of Fender System | 6 | 4 | 0 | 0 |
| 3364-Replace / Construct Fender System | 0 | 0 | 0 | 0 |
| 3366-Drift and Debris Removal | 346 | 314 | 8 | 1 |
| 3368-Installation and Replacement of NBIS Pipes and Culverts | 7 | 5 | 0 | 0 |
| 3370-Maintenance and Repair of NBIS Pipes and Culverts | 63 | 50 | 1 | 7 |
| 3371-Replace Bridge with Culvert | 0 | 0 | 0 | 0 |
| 3372-Bridge Installation & Replacement | 21 | 11 | 0 | 8 |
| 3374-Repair and Maint of Pedestrian Bridges | 3 | 3 | 0 | 0 |
| 3376-Clean/Wash Bridge Decks | 368 | 198 | 76 | 29 |

# APPENDIX C: TOTAL COST OF TOP EXPEDENTURES IN 2014

| Work Task | 2014 | |
|---|---|---|
| | **Total Cost** | **Percent of Total Cost** |
| **Roadside** | | |
| 2900-Grass Mowing | $25,095,789 | 12% |
| 2912-Brush and Tree Control / Mechanical/ Other | $15,448,688 | 8% |
| 2916-Roadside Vegetation Enhancement | $5,187,622 | 3% |
| 2914-Vegetation Management at Stationary Objects | $5,082,336 | 2% |
| 2918-Seeding and Mulching and Fertilization | $3,641,694 | 2% |
| 2904-Turf Management | $1,612,259 | 1% |
| 2908-Brush and Tree Control /Herbicides | $1,058,670 | 1% |
| **Maintenance** | | |
| 3102-Removal of Hazards/Debris From ROW | $20,670,395 | 10% |
| 3112-Shoulder Maintenance / Reconstruction | $19,150,893 | 9% |
| 3108-Drainage Ditch Maintenance | $18,001,571 | 9% |
| 3126-Install Pipes (<=48") | $10,244,311 | 5% |
| 3128-Maint/Repair Pipes (<=48") | $6,884,690 | 3% |
| 3130-Install/ Maintain / Repair of Misc. Drainage Structures | $6,072,289 | 3% |
| 3140-Unpaved Road Stabilization Surface Maintenance | $4,949,620 | 2% |
| 3138-Machining Unpaved Road | $4,307,395 | 2% |
| 3104-Litter Removal | $4,072,549 | 2% |
| 3106-Bagged Litter and Trash Can Pickup | $1,956,745 | 1% |
| 3132-Sweep / Wash Roadway | $1,586,289 | 1% |
| | | |

| | | |
|---|---|---|
| **Traffic** | | |
| 3250-Install / Replace Ground Mounted Signs | $8,882,353 | 4% |
| 3252-Repair Ground Mounted Signs | $6,039,481 | 3% |
| 3222-Long Line Painted Pavement Markings | $5,901,491 | 3% |
| 3244-Temporary Traffic Control | $1,512,186 | 1% |
| 3230-Words and Symbols - Specialty Materials | $1,504,235 | 1% |
| 3226-Long Line Specialty Material Pavement Markings | $1,016,538 | 0% |
| **Bridge** | | |
| 3300-Install / Replace NON NBIS > 48" up to NBIS Structures | $10,571,310 | 5% |
| 3302-Maintain / Repair NON NBIS > 48" up to NBIS Structures | $2,501,117 | 1% |
| 3314-Maintain Steel Superstructure Components | $2,335,555 | 1% |
| 3352-Maint Slope Protection | $2,044,628 | 1% |
| 3366-Drift and Debris Removal | $1,879,341 | 1% |
| 3376-Clean/Wash Bridge Decks | $1,813,106 | 1% |
| 3344-Repair / Replace Timber Substructure Components | $1,784,921 | 1% |
| 3348-Maintain Concrete Substructure Components | $1,595,505 | 1% |
| 3326-Maintain Concrete Deck | $1,210,660 | 1% |

APPENDIX D: BASE YEAR PARAMETERS

| Index | Work Task | Unit | Median Unit Cost | Estimated Total Quantity |
|---|---|---|---|---|
| **Roadside** | 2900-Grass Mowing | SHM | $73.29 | 137,786 |
| | 2912-Brush and Tree Control / Mechanical/ Other | SHM | $530.39 | 15,456 |
| | 2914-Vegetation Management at Stationary Objects | LFT | $0.38 | 22,466,658 |
| **Traffic** | 3222-Long Line Painted Pavement Markings | LFT | $0.04 | 58,572,344 |
| | 3250-Install / Replace Ground Mounted Signs | SFT | $8.03 | 343,389 |
| | 3252-Repair Ground Mounted Signs | EA | $41.04 | 22,367 |
| **Maintenance** | 3108-Drainage Ditch Maintenance | SHM | $17,711.33 | 1,005 |
| | 3112-Shoulder Maintenance / Reconstruction | SHM | $7,626.54 | 2,597 |
| | 3126-Install Pipes (<=48") | LFT | $83.15 | 54,789 |
| **Bridge** | 3300-Install / Replace NON NBIS > 48" up to NBIS Structures | LFT | $1,093.88 | 9,578 |
| | 3302-Maintain / Repair NON NBIS > 48" up to NBIS Structures | LFT | $124.14 | 12,039 |
| | 3314-Maintain Steel Superstructure Components | LFT | $223.03 | 7,228 |

APPENDIX E: SUB-CATEGORY TIERS

| Index | Work Task | 2014 Cost |
|---|---|---|
| Roadside | 2908-Brush and Tree Control /Herbicides | $420,054 |
| | 2904-Turf Management | $578,958 |
| | 2918-Seeding and Mulching and Fertilization | $1,295,128 |
| | 2916-Roadside Vegetation Enhancement | $1,514,526 |
| | 2914-Vegetation Management at Stationary Objects | $2,176,493 |
| | 2900-Grass Mowing | $5,199,471 |
| | 2912-Brush and Tree Control / Mechanical/ Other | $6,567,573 |
| Traffic | 3244-Temporary Traffic Control | $203,790 |
| | 3230-Words and Symbols - Specialty Materials | $309,425 |
| | 3226-Long Line Specialty Material Pavement Markings | $342,024 |
| | 3252-Repair Ground Mounted Signs | $876,852 |
| | 3250-Install / Replace Ground Mounted Signs | $1,986,384 |
| | 3222-Long Line Painted Pavement Markings | $2,223,728 |
| Maintenance | 3132-Sweep / Wash Roadway | $295,706 |
| | 3106-Bagged Litter and Trash Can Pickup | $320,631 |
| | 3104-Litter Removal | $835,577 |
| | 3138-Machining Unpaved Road | $1,342,278 |
| | 3102-Removal of Hazards/Debris From ROW | $1,861,711 |
| | 3140-Unpaved Road Stabilization Surface Maintenance | $2,276,862 |

| | | |
|---|---|---|
| | 3130-Install/ Maintain / Repair of Misc. Drainage Structures | $2,370,170 |
| | 3128-Maint/Repair Pipes (<=48") | $3,214,871 |
| | 3126-Install Pipes (<=48") | $5,986,258 |
| | 3112-Shoulder Maintenance / Reconstruction | $9,062,249 |
| | 3108-Drainage Ditch Maintenance | $9,097,899 |
| **Bridge** | 3376-Clean/Wash Bridge Decks | $571,757 |
| | 3366-Drift and Debris Removal | $884,517 |
| | 3348-Maintain Concrete Substructure Components | $828,245 |
| | 3326-Maintain Concrete Deck | $927,847 |
| | 3344-Repair / Replace Timber Substructure Components | $1,015,076 |
| | 3352-Maint Slope Protection | $1,048,244 |
| | 3314-Maintain Steel Superstructure Components | $1,315,239 |
| | 3302-Maintain / Repair NON NBIS > 48" up to NBIS Structures | $1,630,306 |
| | 3300-Install / Replace NON NBIS > 48" up to NBIS Structures | $8,162,600 |

Tier 3
Tier 2
Tier 1