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Fleet Management Criteria: Disposal Points and Utilization Rates

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16. Abstract

The goals of this study were to determine, for six equipment classes (three on road and three off road), a methodology for evaluating aging (or depreciation), disposal points, and overall utilization. The primary deliverable was development of a decision model which would help reduce cost, improve the age of the fleet and its readiness to serve the public, and improve overall utilization. The study identified an approach to segment or tier equipment utilization based on usage purpose so that specific needs and supporting equipment could be more readily identified by management. The study examined salvage values and identified trends in market value decline based on historical records. Using internal cost information, the study identifies trends in cost of operation and use as equipment ages. This information was integrated into an optimal economic life model based on equivalent uniform annual cost to identify the optimal disposal point for the six classes. The analytical models developed in the study provide a foundation for long term analysis of fleet size and the cost effectiveness of disposal points.

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Executive Summary

The primary goals of this study were to determine, for six classes of equipment (the largest NCDOT groupings: pickup trucks, single axle dump trucks, flat bed and miscellaneous, loader-backhoe, motor grader, and front end loader), a methodology for evaluating aging (or depreciation), disposal points, and overall utilization. The management direction expressed at our initial project meeting primarily involved development of a practical decision model approach which would reduce cost, improve the age of the fleet and its readiness to serve the public, and improve overall utilization.

To complete the specified scope, we employed data from the NCDOT enterprise information system (SAP) and employed statistical and engineering economics models. Our study was divided into three phases. In the first step we gathered and analyzed cost and utilization data for the six target classes for the four year period from 2006-2009. The second step involved meetings and conference calls to review the data gathered and analysis developed with key equipment experts from three divisions which represented the primary geographical regions of the state (mountain, piedmont, coastal). Our goal in the second step was to develop operational understanding of the SAP data by obtaining practical insights into day to day operations of the divisions and the various departments. Finally we integrated the data analysis and the practical operational needs of the divisions into a composite decision model which meets the goals of the study and provides a path forward for NCDOT management to meet its original goals of improving the cost effectiveness of the current assets in these six classes.

We segment our findings and recommendation into four categories: 1) Operational perspectives; 2) Data accuracy and information system considerations; 3) Equipment utilization targets; 4) Long term recommendations to implement the findings of this study or identify improved approaches.

Operational Perspectives

During the four years covered by our study, it is important to recognize the interplay of several organizational factors which impacted equipment planning, fleet size, and utilization decisions. While our data covers the period of implementation, growth, and integration of the SAP system, it also represents a time of significant organization change and budget uncertainty.

- Personnel reduction and NCDOT operational direction: Over the last several years, significant budget cuts, increased outsourcing, and personnel reductions have occurred. The change in focus and operations resulting from these events were, and continue to be, slowly integrated into day to day practices and decisions. This has had a negative impact on utilization. For example, one perspective is that it is in the best interest of NCDOT to hold old equipment in the event that vacant positions are filled. This understandable, but perhaps unrealistic, view of the future drags down utilization
- Budget inconsistency: The recent variation in budget funds available to execute specific categories of work has had significant impact on work patterns and available manpower. Consequently, a number of work planners have felt the need to maintain high equipment levels to support a wide range of work options to assure productivity of the current workforce.

It is important that the continued analysis of this data continue during the next several years as these changes become less erratic and the data becomes more accurate and representative of day to day operations.

Data Accuracy and Information System Procedures

Implementation of an enterprise wide data base (such as SAP) is a critical management tool and this study would not have been possible without the information from this system. NCDOT management should be commended for initiating this study at the earliest time when the system contains sufficient information (four years) for decision analysis. As an ongoing goal, there are several implementation issues which should continue to receive attention:

- Training and consistency of data entry: It is evident that data entry procedures related to equipment operation and utilization were not consistent for the four year time period of our study data. Although the units are continuing to work on this issue, it is important that clear manuals and appropriate training and auditing are emphasized
- Understanding of the financial system for asset cost charging, renewal and project cost: An issue related to data entry is that many individuals in the division do not understand that understatement of utilization is detrimental in the long term. There is some level of misunderstanding of charging equipment cost to a project compared to charging time related to utilization.

The net effect of these two issues is understatement of utilization. We believe this has been a consistent issue across divisions, over the four years of our study. Going forward, it will be increasingly important to have confidence in the accuracy of the system information and this will be achieved with constant effort to enhance consistency and understanding.

Equipment Utilization Targets

From an operational perspective, there are several recommendations which cut across all of the six classes we studied. An underlying theme is that, with the diverse mission and complex challenges NCDOT faces, equipment should be classified and utilization tracked based on a more discrete segmentation scheme than is currently used. We recommend a segmented approach to utilization goals with at least two levels, and possible consideration for a third tier:

- Tier 1: Day to Day Use Units: The data shows that in each studied class there is a large group of highly utilized equipment employed for day to day operational needs. We recommend this equipment be segmented and utilization targets for this group should exceed 40%. We make more specific recommendations for each class in the body of the report.
- Tier 2 Spares or Backup Units: There is a significant operational need involving important but inconsistent needs such as spare, seasonal, or back up units. There are a number of divisions which have employed rental arrangements to address these needs and these agreements should be shared as possible best practices. For equipment needs where rental is not appropriate, we recommend equipment pooling either within the divisions or on a state wide basis. Equipment appropriate for this tier should have utilization between 20% and 40%. Once again the report contains more detailed discussion of each class.
- Tier 3 Emergency Units: We anticipate tier 2 equipment numbers or special lease / rental agreements will be capable of emergency needs coverage. In the event that special needs are identified beyond the numbers in tier 2 or rental, we recommend establishing a third utilization tier. In general, if this category is needed, the equipment should be placed on

a special (perhaps administrative) status so it does not negatively impact the tier 1 and 2 utilization goals. The need for this equipment should be reviewed annually to assure the continued need.

- Disposal- Low Utilization Targets: In general, equipment utilized less than 20% should be targeted for removal from the fleet.
- Equipment with Seasonal Variation or Special Purpose Use: Relative to day to day needs, there are several equipment classes which present special issues such as seeders which are seasonally oriented, or line painters. These equipment classes should be individually evaluated based on the potential for use. For example, an adjusted seasonal utilization target could be identified based on the maximum months of potential utilization. Similarly, equipment necessary for support purposes may be considered for administrative status. This recommendation has particular application to class 0206 which contains approximately 20 different truck types.

Long Term Implementation

The organization has been working over the four years of our study data to manage the SAP data, right size the fleet, and increase utilization. It is important to formalize these efforts and this section addresses several alternatives.

- Implementation Task Force: A project team should be formed and tasked with identification of operational guidelines, classification of equipment, development of a project plan, and monitoring progress for a continuous improvement process targeted at adjusting the fleet size and improving utilization and cost effectiveness.
- Ongoing Utilization and Data Analysis: The project team and operating management should be furnished with periodic data summaries, such as included in this report, as an aid in monitoring progress and improving performance. It is particularly important to continue to track and update data on variables which can impact the economic life model such as salvage value and the rate of operating cost increase per year.
- Divisional Rental Rates: A comprehensive and system wide improvement project such as this report describes must have wide organizational support. An essential tool to accomplish this is to assure that the divisions benefit from the results by implementing a system of division rental rates which assure positive benefits flow back to those who embrace change and improvement.
- Ramp up of New Unit Utilization: The current procedure for integrating new equipment into the SAP utilization tracking system entails a negative impact in overall utilization. An improved approach should be implemented so that new equipment utilization is accurately tracked.

Summary of Recommendations

In developing recommendations, we identified three essential constraints at this point in the improvement process to meet the project goals.

- Data variability: The utilization data reflected in the SAP system has significant variability. As noted earlier, common errors in the current system tend to understate utilization.
- Practicality: Utilization targets must be achievable within the constraints of the diverse mission elements of NCDOT.

- Assurance of public safety: Finally and most important, utilization targets must provide the capabilities to meet the key mission to protect the investment in the road system and assure public safety.

The table below summarizes the recommendations from the body of the report and provides the foundation for achieving the project goal of increasing fleet capability while reducing cost and increasing utilization. We believe these goals are achievable in the near term.

Class	2009 fleet size	Proposed fleet size	2008 utilization	Proposed composite utilization target	Economic Life
0201 pickup truck	1366	1160	0.63	> 0.75	8-9 years
0205 single axle dump	1038	744	0.45	> 0.60	8 years
0206[1] flat bed "truck2"	379	244	0.37	> 0.55	9 years
0314 loader-backhoe	297	222	0.48	> 0.60	8 years
0900 motor grader	434	295	0.39	> 0.55	11 years
2002 [2]front end loader	216	190	0.37	> 0.60	12 years

Note 1: Segment other categories in this class
Note 2: Fleet units on yard duty placed on administrative status

1 Project Introduction and Overview

This project report addresses the research objectives described in the request for proposal (RFP) titled "Fleet Management Criteria: Depreciated Life, Disposal Points, & Utilization Rates Study." In that RFP, the following research objectives and tasks were noted:

Objective 1: Develop a methodology for determining (a) an appropriate rate of depreciation, (b) an appropriate point for disposing of equipment, and (c) an appropriate level of utilization for the fleet.

Objective 2: Once the methodology has been identified and verified for all three areas, the researcher will apply that methodology to equipment data provided by NCDOT. The researcher will determine actual depreciation rate, disposal point, and utilization rate for six class codes of equipment. NCDOT will provide data focusing on these six representative class codes of equipment, which represent the greatest number of pieces representing the largest investment to the Department. Three of the class codes will be "on road" and three will be "off road".

To accomplish these objectives, three tasks were identified and are described below.

Task 1: Depreciated Rate of the Fleet

Develop a methodology for determining an optimum overall depreciation level. Researcher will then apply that methodology to determine that optimum rate for the current NCDOT fleet. The question to be answered is what overall percentage of a fleet should be depreciated out at any one point in time to be reflective of an efficient fleet operation?

Task 2: Disposal Point for Equipment:

Develop a methodology for determining the appropriate point of disposal for the six equipment class codes mentioned above. Every piece of equipment in the NCDOT fleet has an optimum point of disposal. The goal is to dispose of each piece of equipment before major repair costs take an exponential jump.

Task 3: Utilization of Equipment:

Develop a methodology for determining the appropriate amount of utilization for each of the six representative class codes. NCDOT has determined that in most cases it is more cost effective to own the majority of the fleet. What we are interested in determining now is how many pieces of these six class codes are needed based on the amount of time the piece of equipment will be used.

This report addresses these goals and tasks.

1.1 Literature Search

A large number of publications address the issues of fleet management. However, we did not find any published works to guide us specifically in addressing the goals of the project.

Consequently we used the literature search to provide general benchmarks for our analytical approaches. The next paragraphs highlight the literature most germane to our work.

Many of the publications found were focused on specific types of fleets, such as those of freight carriers, rental companies, transit authorities, or the military. For example, Wyrick and Storhaug (2003) benchmarked the best practices in fleet management of a number of private companies and public entities, including state Departments of Transportation. One of their findings was that most state DOT's were in the early stages of developing performance measures to assist in fleet management.

Two of the more applicable reports for this project dealt specifically with state Departments of Transportation. The most recent of these reports, prepared for the Oregon DOT (Kim et al, 2009), provides a summary of the types of models that have been used to make replacement decisions, including computation of an economic life, utilization of repair cost limits, and comprehensive cost models. One finding from their research was that decreasing utilization as a function of age was not considered in most models. That is, a constant utilization rate was assumed in the models. The Oregon report concluded that if a simple ranking criterion is to be used to prioritize replacement decisions, then equipment age, rather than other factors such as maintenances cost, utilization rate, etc., is the most cost effective model. If equipment is utilized in a manner such that newer equipment is generally preferred over older equipment (such as would be expected in a DOT fleet), then the overall fleet operating costs will be higher than if the equipment is equally utilized.

A report prepared for the Virginia DOT (Gillespie and Hyde, 2004) found that a relatively good correlation between a unit's variable cost as a function of the fuel costs for that unit could be made with a logarithmic model, but the data contained a great deal of variation. Much of this variation could be attributed to differences in how data was entered into the state's database. The Virginia report recommended that an estimate of the cost of operation for the next year could be obtained by computing the ratio of labor and parts cost per fuel dollar year to date to the labor and parts cost life to data. A limitation to utilizing this approach was the amount of data that was deleted at each year end. The report recommended that more cost data be archived to achieve more confidence in cost modeling. One interesting finding from the Virginia report was that data pickup trucks, because their usage is so different from other pieces of equipment considered, did not fit any of the proposed models well.

A key conclusion from reviewing the literature is that the validity of any model is dependent on the availability and accuracy of the data available. Repair and maintenance costs are by their nature extremely variable and, as a result, highly accurate correlation of fleet data to any model is unrealistic.

The entire body of literature reviewed for the project is summarized in the annotated bibliography of Appendix A.

1.2 Project Data Collection

Yearly operational and utilization data for each piece of equipment was acquired from three different sources within NCDOT's SAP System and related Business Warehouse (BW) system.

The NCDOT SAP system contained equipment identification data and yearly operational data. The NCDOT BW system contained equipment utilization data. Each type of data acquisition is described in further detail in the following sections.

1.2.1 Equipment Identification

The first phase of data acquisition involved the Equipment Identification information within NCDOT's SAP System and acquired using the IH08 module. Query inputs included the following:

- Equipment Category: "D" (to specify NCDOT equipment only)
- Inventory Number: "*####" (#### is the four-digit equipment class)
- Status Included: "E0, E1, E2, E3" (E0 = Available for Transfer; E1 = Repair or In Shop; E2 = In Service – On Rent; E3 = Wrecked)
- Maintenance Plant: (Maintenance Plant (four-digit numeric code that identifies each of the fourteen NCDOT divisions. The first two digits identify the division (01 to 14) followed by the characters '10'.)

The following fields were captured for each equipment class and division under study:

- Equipment Identification (unique eight-digit indexed numeric code that SAP generates for each new piece of equipment documented in the SAP system)
- Equipment Class (four-digit numeric code which identifies each class under study: "0201", "0205", "0206", "0314", "0900", or "2002")
- Inventory Number (assigned twelve-digit numeric formatted code "####-####-####" that identifies each piece of equipment. The last four digits identify the equipment class.)
- Equipment Description (alphanumeric equipment class description)
- Functional Location (sixteen-digit alphanumeric formatted code "###-######-######-####" assigned for each piece of equipment. The last four digits identify the equipment class.)
- Maintenance Plant (four-digit numeric code that identifies each of the fourteen NCDOT divisions. The first two digits identify the division (01 to 14) followed by the characters '10'.)
- Acquisition Date (date that the equipment was acquired)
- Start-Up Date (date that the equipment was first used)
- Model Year (approximate year that the piece of equipment was manufactured, usually either the actual year specified or the year before; also identifies base product specifications)
- Manufacturer (the name of the company or corporation which manufactured the piece of equipment)
- Model Number (model nomenclature that identifies the specific equipment construction or chassis)
- Acquisition Value (purchase price of the equipment)

The specified fields were saved in a layout in the IH08 transaction module to ensure all information derived for each SAP query was consistent. Results for each query were exported from SAP into Excel 2003 found within NCDOT's domain. The information was subsequently copied from Excel 2003 (in NCDOT's domain) to Excel 2007 (located "locally".)

1.2.2 Operational Cost

The second data acquisition step involved operational cost information located in NCDOT's SAP system in the #### module. The following fields were automatically captured for each queried operation year and equipment class under study:

- Equipment Identification (unique eight-digit indexed numeric code that SAP generates for each new piece of equipment documented in the SAP system)
- Rental income
- PM labor costs
- Repair PM costs
- Cost of fuel
- Cost of oil
- Cost of tires
- Total actual costs
- Profit/loss figures
- Miles (driven) (for Classes 0201, 0205, 0206, and 0314)
- Operating hours (for Classes 0900 and 2002).
- Rent hours
- Cost/rent hours
- Revenue per hour
- Profit per hour
- Available hours

The query results were exported from SAP into Excel 2003 in NCDOT's domain. The information was subsequently copied from Excel 2003 (in NCDOT's domain) to Excel 2007 (located "locally".) Although all previously noted fields were captured, only the following fields were required for the equipment analysis: Equipment Identification, Total Actual Costs, Miles, Operating hours, Available hours, and Rent hours.

1.2.3 Utilization

Equipment utilization information is located in the NCDOT's Business Warehouse (BW) under the Equipment Utilizations by Notification module. Each query specified the operational year (January 1 to December 31) and equipment class. The following fields were automatically captured with each query:

- Maintenance Plant (formatted as "Div # Equipment and Repair", where # represents one of the fourteen division numbers).

- Equipment Old Class Code (the four-digit numeric code which identifies each class under study: “0201”, “0205”, “0206”, “0314”, “0900”, or “2002”)
- Inventory Number (assigned twelve-digit numeric formatted code “####-####-####” that identifies each piece of equipment. The last four digits identify the equipment class.)
- Fuel Used (amount of fuel used, in gallons, in the given operational year for each piece of equipment).
- Rent Hours (total number of rental hours in the given operational year as documented in BW).
- Available Hours (total number of hours in which equipment could potentially be rented in the given operational year).
- Utilization % (ratio of rent hours to available hours expressed as a percentage).

The query results were “copied” from the Excel (BW in NCDOT’s domain) to Excel 2007 as a “local” file. The “local” files were further refined so that each record (individual piece of equipment) had the operational year and four-digit class code documented. An additional inventory number field was created in the equipment utilization data to ensure formatting was compatible (“exact”) between the inventory number fields found in the SAP equipment identification data and BW utilization data.

1.3 Report Organization

The remainder of the report is organized to present the logical flow in developing the information necessary to develop the optimal life model.

- Chapter 2 examines equipment utilization, age, and usage data, by division and region, to provide a foundation for estimating fleet size and the impact of fleet changes.
- Chapter 3 uses NCDOT salvage records and market place data to develop forecasts of market value and the rate market value declines for the six classes.
- Chapter 4 examines operational cost growth with age and analyzes trends in equipment operation based on age.
- Chapter 5 develops uses the relationships developed in chapters 2-4 to develop the optimal life models for each class. These models are analyzed for sensitivity to possible changes in model factors such as market value, rate of increase of operating cost and other factors.
- Chapter 6 concludes the report with a summary and recommendations for next steps

2 Equipment Utilization

As a foundation for the economic life model, this section examines the 2006-09 data base for information and trends related to usage and utilization of the six equipment classes. The information is presented by class code and examines statewide, geographical region, and division differences. One target for the study involved determining whether the economic life model should be differentiated based on the three geographic regions of the state. Figure 1 provides a geographic view of the divisions:

- Coastal: Divisions 1-4
- Piedmont: Divisions 5-10
- Mountain: Divisions 11-14

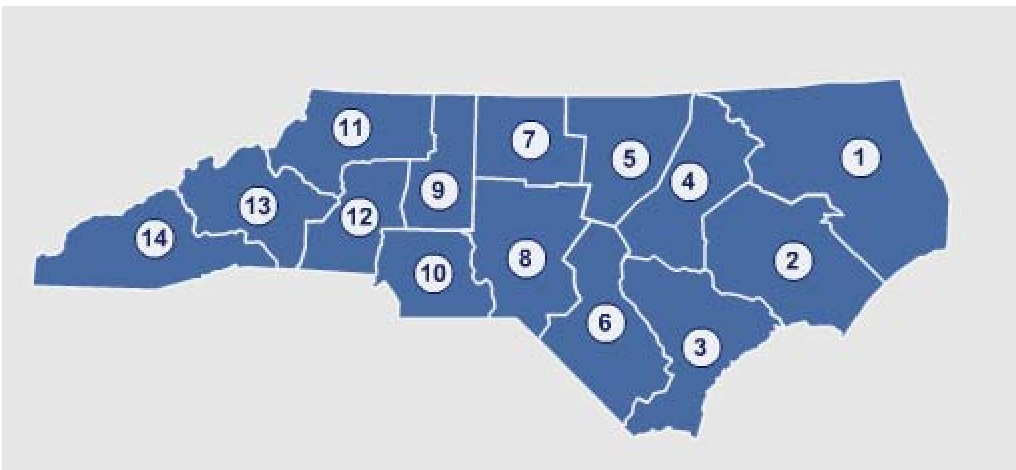

Figure 1 NCDOT Divisions

The remainder of this chapter is structured based on the six classes of the study.

- Class 0201 pickup trucks
- Class 0205 single axle dump trucks
- Class 0206 flat bed and miscellaneous trucks
- Class 0314 loader-backhoe
- Class 0900 motor grader
- Class 2002 front end loader

Utilization is the ratio of the number of hours a piece of equipment is charged (rented) divided by the number of hours it is available for use. In general, an item begins with 2088 hours available and this value is then reduced by events such as repair, planned maintenance, or events resulting in non availability for use. As the SAP system has been introduced, there has been inconsistent interpretation on how to charge hours related to utilization. For example, in some cases an asset might be on a job for eight hours but operated only two. In this case, the item should be charged eight hours for utilization and not two. Since this is procedure has not been consistently applied, there is some level of understatement of utilization in the data used for this report. An important recommendation from this study is that a program to better assure consistent data entry practices be initiated so that future information will be more reflective of actual utilization. This point and other issues impacting utilization in general are discussed in the next paragraph and related bullet points.

To develop better understanding of the data in this section, a number of face to face meetings and teleconferences were conducted to facilitate data gathering, promote understanding of the goals of the project, and explore issues which positively or negatively impacted utilization. NCDOT personnel consistently raised several organizational issues which impact the report:

- Personnel reduction and NCDOT mission: Over the last several years, significant budget cuts, increased outsourcing, and personnel reductions have occurred. The change in focus and operations resulting from these events has not been integrated into day to day practices and decisions. For example, one common belief is that it is in the best interest of NCDOT to hold old equipment in the event that vacant positions are filled. The reality is that the eliminated positions will likely not return and adjustments to the equipment fleet are needed. To improve utilization, it will be essential to match the current mission of NCDOT, the work required to accomplish the mission, the role of the workforce, and the equipment mix required to support mission and employees.
- Budget inconsistency: The recent variation in budget funds available to execute specific categories of work has been significant. Consequently, work planners have felt the need to keep equipment levels which support a range of work options which may be required to assure productivity of the current workforce.
- SAP procedures: This issue was mentioned above. To manage the fleet, it will be important to establish and train the workforce on consistent data entry practices so that the system data reflects equipment activities accurately.
- Cost system and conflicting goals: An inconsistent understanding of how equipment use charges impact project budgets, division budgets, and equipment replacement further complicates the mission, budget, and SAP issues noted above. As a result, it is not infrequent that NCDOT personnel believe it is correct to charge operating hours and not rental hours to a project.

The following sections examine utilization, usage (miles or hours), and age of each class. Beginning with an overview, four year and one year utilization data along with mileage or operating hours are presented. Next, division and regional comparative data and age trends are discussed. Finally, the sections end with discussion of utilization and fleet size target recommendations which will be employed in the optimal economic life model for each class developed in Chapter 5.

These recommendations for utilization and fleet size are made in the following guidance:

- Differentiated utilization targets: Uniform utilization targets are not helpful in managing a complex equipment system. Rather, varied utilization targets, recognizing the specific, primary purpose of each piece of equipment would enhance a more productive analysis of organizational needs. For example, for the six classes of this study, we have employed a basic system of two equipment categories: 1) needed for day to day operation; 2) needed as a spare for day to day operation (at a division or central location). A third possible division may include those units needed as an emergency unit (for snow, storm or other emergency) required beyond the units in the spare category. For the purposes of this study, we have combined these last two categories together.

- Ongoing utilization management and analysis: A utilization team should be formed and tasked with identification of operational guidelines, developing a project plan, and monitoring progress for over what should be a continuous improvement process to adjust the fleet size and improve utilization and cost effectiveness.

Discussion of utilization and fleet size targets must consider several factors:

- Data variability: It is clear that utilization data gathered from the SAP system has significant variability. As noted earlier, common errors in the current system tend to understate utilization.
- Practicality: Utilization targets must be achievable within the constraints of the diverse mission elements of NCDOT.
- Assurance of public safety: Finally and most important, utilization targets must provide the capabilities to meet the key mission to protect the investment in the road system and assure public safety.

In general, the report finds it is possible to eliminate low utilized assets, improve the age of the fleet, and increase utilization.

2.1 Class 0201 Pickup Truck Overview

Table 1 presents basic trend information related to pickup truck fleet size and usage over the 2006-2009 study periods. In general, the fleet has grown from 1032 vehicles in 2006 to 1366 in 2009. Total miles driven by this fleet ranged from thirteen to fifteen million miles with the average miles per vehicle per year varying from a high of 13,558 miles in 2006 to a low of 9,670 in 2009. Average utilization varied from a high of 0.65 in 2006 to 0.57 in 2009 (erratic budget year) and average rental hours also ranged from a high of 1,377 in 2006 to a low of 1,258 in 2009. In spite of growth of the fleet, utilization has been consistent across the three years of more typical operations (2006-2008).

Table 1 Pickup Truck Fleet Size and Use Trends, 2006-09

	2006	2007	2008	2009
Average vehicle miles / year	13,558	10,589	11,076	9,670
Units in the fleet	1,032	1279	1,383	1,366
Total miles	13,992,014	13,543,151	15,318,182	13,208,714
Average utilization	0.65	0.63	0.63	0.57
Average rental hours	1377	1248	1329	1258
Average available hours	2042	1966	2032	2064

Figure 2 shows the overall utilization[1] distribution of class 0201 for the period of the study. Note that for the histograms in this report, the column label represents the largest value contained in that bin. For example, the "40%" bin in Figure 2 contains the data points which are greater than 20% but equal to or less than 40%. The data indicates that 18% of the vehicles over this four year period (921 trucks) were utilized less than 20% of the available hours. 32% of the vehicles (921+694) were utilized less than 40% of the available hours.

[1] Utilization is defined as the ratio of the number of hours the item was assigned on a task or project (and not available for other use) divided by the number of available hours. In general the maximum hours available per year are 2088 and hours when the item is in the shop for repair are deducted from available hours.

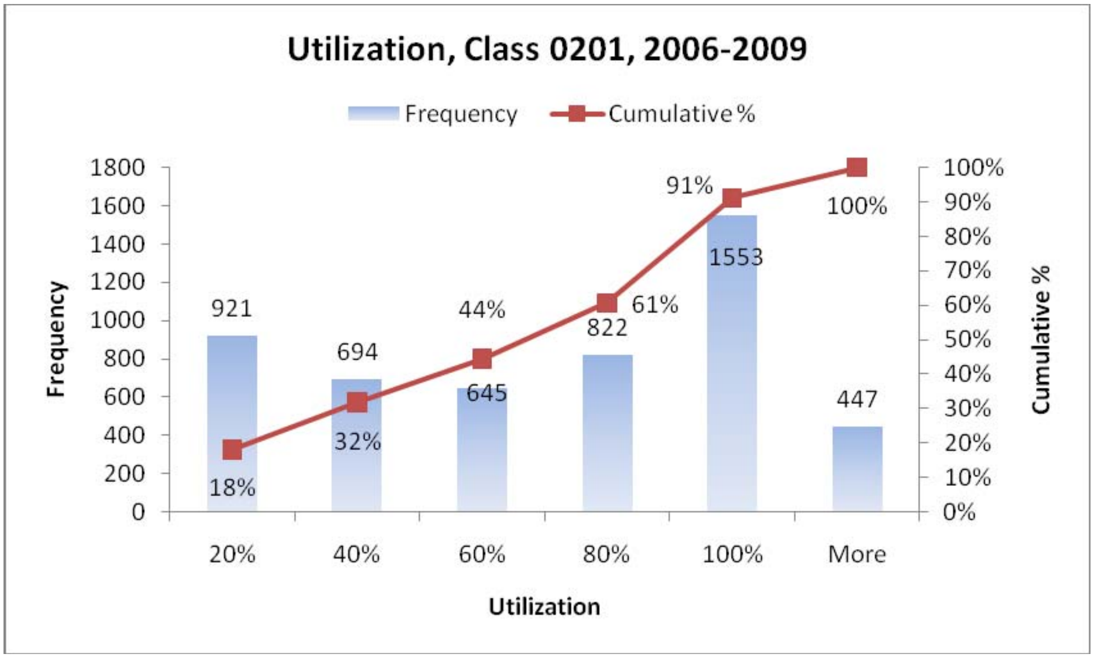

Figure 2 Utilization, Class 0201 Pickup Trucks, 2006-2009

Since 2009 was a year which involved significant curtailment of normal NCDOT activities based on the state and national economic situation, 2008 was selected as a more representative year to reflect current operational practices for class 0201 pickup trucks. Figure 3 shows the utilization distribution for that year and indicates that the general patterns shown in Figure 2 for the 2006-2009 time periods were consistent with 2008.

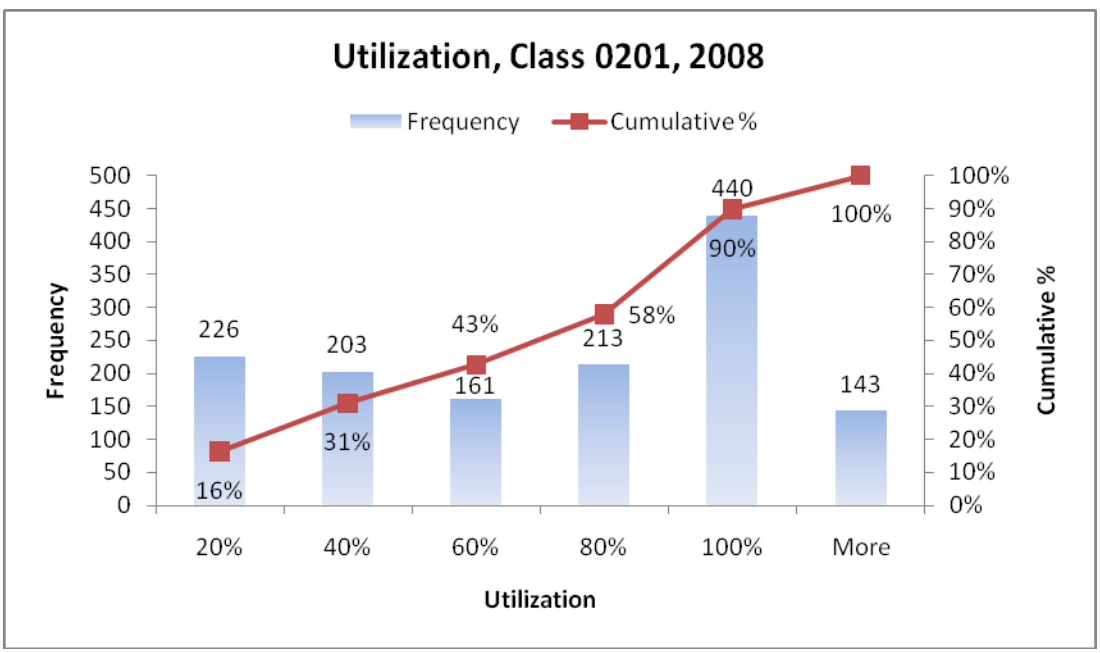

Figure 3 Utilization, Class 0201, 2008

Figure 4 presents the data for the distribution of annual mileage for 2008 and shows that about 7% of the units (95) were driven less than 2,000 miles, 16% (127) were driven less than 4,000 miles, and 27.4% (95+127+157) were driven less than 6,000 miles.

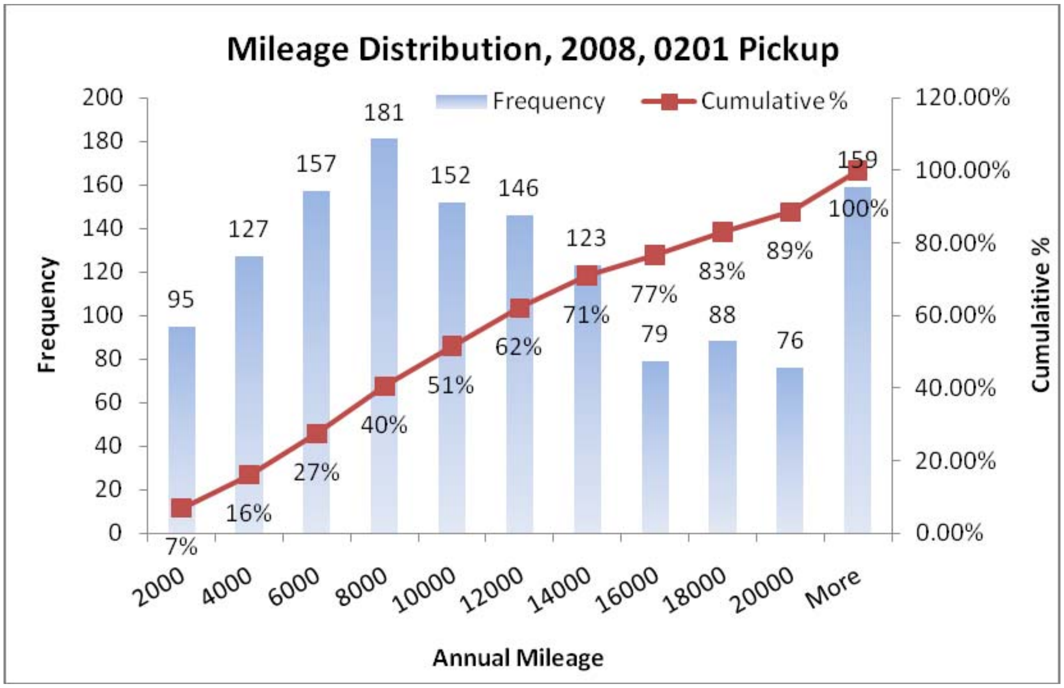

Figure 4 Mileage Distribution, Class 0201, 2008

2.1.1 Class 0201 Pickup Truck Utilization by Division

Table 2 provides a summary of the mean utilization for 2008 segmented by division. Mean utilization in 2008 ranged from a low of 45% for division 11 to a high of 77% for division 6. The brackets on the right side of the table represent a 95% confidence interval for the mean annual utilization of the division based on 2008 data, calculated using equation 1 below, where s is the pooled standard deviation, n is the number of data points for the division, and t (α/2, n-1) is the t distribution value based on 95% confidence and n-1 degrees of freedom.

Confidence interval = $mean \mp t\left(\alpha\frac{}{2}, n-1\right)\left(\frac{s}{\sqrt{n}}\right)$ **Equation 1**

Throughout this section, tables similar to Table 2 are presented to compare equipment use levels across divisions and regions. Lack of overlap in the confidence interval brackets in Table 2 indicates a statistically significant difference at the 95% confidence level in average division utilization. For example, the bracket for division 11 does not overlap the bracket for division 12, indicating the utilization is significantly lower in division 11 than 12 at a 95% confidence.

Table 2 Pickup Truck Utilization by Division- 2008 data

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled St Dev
Division   N      Mean     St Dev  -----+---------+---------+---------+-
 1        138    0.5414    0.3346         (---*---)
 2        102    0.6405    0.3694               (----*---)
 3         98    0.5704    0.3542          (----*----)
 4        143    0.6322    0.3390               (---*---)
 5        109    0.7114    0.3721                    (---*----)
 6        132    0.7765    0.4006                         (---*---)
 7        104    0.7177    0.3851                    (----*---)
 8        133    0.6533    0.3057                 (---*---)
 9        120    0.6134    0.3523              (---*---)
10         55    0.5878    0.3523          (-----*-----)
11         87    0.4515    0.3007  (----*----)
12         80    0.6497    0.3620               (----*----)
13         16    0.6092    0.3173      (-----------*----------)
14         69    0.5965    0.3261           (-----*----)
                                   -----+---------+---------+---------+-
Pooled St Dev =   0.3515               0.45      0.60      0.75      0.90
```

Table 3 provides the average annual miles for class 0201 vehicles for 2008 by division. In general, the coastal divisions (1-4) have higher average annual miles than the piedmont or the mountain divisions.

Table 3 Pickup Truck Average Annual Miles by Division- 2008 Data

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled St Dev
Division    N       Mean      St Dev -------+---------+---------+---------
 1        138     12503      7511                        (----*----)
 2        102     12503      7722                       (-----*-----)
 3         98     12158      7533                      (-----*----)
 4        143     12312      8362                       (----*----)
 5        109     11042      8006                  (----*-----)
 6        132     11695      7060                     (----*----)
 7        104     10340      6881               (----*-----)
 8        133     12177      6741                       (----*----)
 9        120      8389      6750       (-----*----)
10         55      7915      5390   (-------*------)
11         87      9795      6542            (-----*-----)
12         80      8056      7581     (-----*------)
13         16      9808      7082    (-------------*------------)
14         69     11993      6625                    (------*------)
                                  -------+---------+---------+---------
Pooled St Dev =     7267                7500     10000     12500
```

Comparison of Tables 2 and 3 highlights the important point that high mileage and high utilization do not necessarily coincide. For example, a pickup truck may be utilized 100% on a given day since an inspector drives it to a construction site. However, the round trip mileage may be only ten miles. If this happened every day in a 250 day work year, the result would be 100% utilization and 2,500 miles.

2.1.2 Class 0201 Pickup Truck Utilization by Region

Table 4 and 5 present average annual utilization and mileage by region for 2008.   Table 4 indicates the piedmont region utilization is significantly higher than either the coastal or the mountain regions. On the other hand, Table 5 indicates that the coastal regions have statistically significant higher annual mileage than the mountain or piedmont regions.

Table 4 Pickup Truck Average Annual Utilization by Region- 2008 Data

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled St Dev
Level      N      Mean     St Dev  ----+---------+---------+---------+--
Coastal   481    0.5953    0.3490          (----*-----)
Mountain  252    0.5641    0.3379   (------*------)
Piedmont  650    0.6883    0.3647                        (----*---)
                                   ----+---------+---------+---------+--
Pooled St Dev =   0.3545              0.540     0.600     0.660     0.720
```

Table 5 Pickup Truck Average Annual Miles by Region- 2008 Data

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ------+---------+---------+---------+
Coastal   481     12376      7799                        (----*-----)
Mountain  252      9846      7066  (-------*-------)
Piedmont  650     10591      7074           (---*----)
                                   ------+---------+---------+---------+
Pooled StDev =     7333                  9600     10800     12000     13200
```

2.1.3 Age Trends – Pickup Trucks

Table 6 summarizes trends on age of the 0201 pickup over the 2006-09 data period and shows an increase in the mean age of the fleet, the median age (50% older and 50% younger), and an increase in units over ten years old from 47 (~ 5% of the fleet) to 363 (~ 26% of the fleet).

Table 6 Age Trends for Class 0201 Pickup Truck

	2006	2007	2008	2009
Mean age (years)	6.3	6.0	6.5	6.9
Median age (years)	4.58	5.50	5.56	6.56
% fleet < 10 years	95.4%	85.2%	79.9%	73.6%
Count > 10 years	47	189	278	363

2.1.4 Summary- Utilization of Pickup Trucks

This section examined the utilization, age, and usage trends for the class 0201 pickup truck. Key points include:

- Overall fleet utilization in 2008 was 63% with 226 units or 16 % of the fleet below 20%. Similarly 16% of the units were driven less than 4,000 miles in 2008.
- Currently nearly half the divisions are near or above the 65% level and this group includes divisions in each geographical region. Two divisions in the piedmont region are above 70%. (excluding division 6)
- Only 32% (440 units) had utilization between 80% and 100%.

Additional investigation of the underutilized equipment found that 33% of the 226 units utilized less than 20% (71) in 2008 were associated with introduction of new units to the fleet as evidenced by the number in the one and two year age interval in Figure 5. Consequently, the more precise number of units utilized less than 20% is 155 or 11% of the fleet.

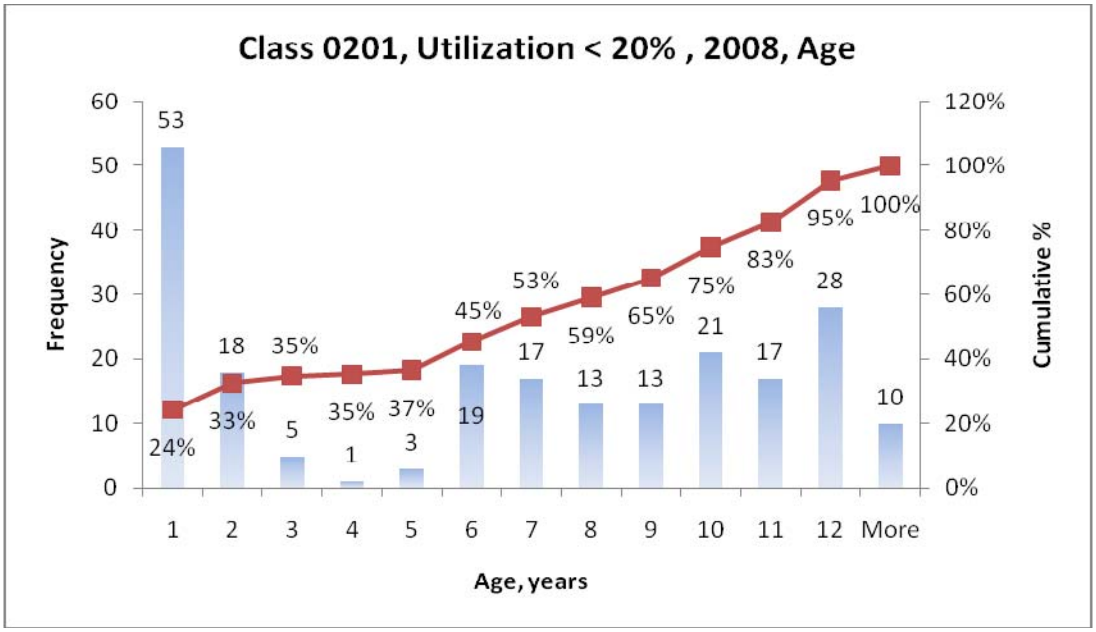

Figure 5 Age of Class 0201 Utilized <20% in 2008

Discussions with division personnel to examine possible avenues for utilization improvement identified several issues which contribute to the inclination to maintain a fleet size capable of meeting sporadic and changing needs instead of consistent, base line needs. This negatively impacts utilization:

- There is a seasonal aspect to the need for and utilization of these trucks. Examples include summer hires (students) and the ebb and flow of construction related needs such as inspection.
- Sporadic needs for training and meetings encourage decisions to maintain vehicles for this requirement. It is not common practice to drive personal vehicles and be reimbursed for that expense.
- As noted, there is inconsistency in charging the trucks in the SAP system. This is an issue for all of the classes studied but trucks out on a job for a day may not be charged the

whole day but only the time they are actually operated. This results in reduced utilization.
- Personnel in the divisions have been reduced over the last several years based on budgetary and strategic directions. In some cases vehicles have been maintained based on the belief that some lost budget positions may be restored.

The following options were suggested as practical alternatives to increase utilization:
- Pooling on a division level is feasible in addressing some of the erratic needs. It is generally agreed that a centralized spare fleet is feasible.
- Sharing of trucks across department boundaries would also increase utilization. Currently this is not frequently done.
- Exploring short term rental to meet seasonal, temporary employee, or intense construction project needs.
- Use of personal vehicles for sporadic needs such as training or meetings.
- Decrease the ramp up time from the point of new equipment purchase to high utilization.

Based on our study of the class 0201 units, Table 7 presents the proposed targets for fleet size and utilization.
- Reduce the 0201 fleet by 11% by eliminating 155 units utilized less than 20%.
- Develop two classifications with separate utilization targets.

  Day to day operation: The first category covers equipment with a consistent day to day mission as represented by units with a current utilization over 40%

  Spare or pool units: The second utilization category covers units which are maintained, either centrally or divisionally, for meeting sporadic, pool, or spare need. Units with current utilization between 20% and 40% currently represent this group of equipment.

Table 7 Proposed Class 0201 Fleet Composition

	Units	% Fleet	Average Util.	Total Miles	Average Miles
Utilization > 40% (day to day operation	957	82.5%	0.83	12,195,825	12,744
Utilization 20%-40% (spare, pool, or sporadic use)	203	17.5%	0.31	1,835,777	9,043
	1160	Composite Util. =	0.74		

Table 7 shows current (2008) data and indicates that elimination of the low utilized equipment and redistribution of those miles and use hours would result in a class 0201 fleet with a composite utilization above 75%, utilization of day to day use items above 85%, and utilization of the spare / emergency pool above 35%.

2.2 Class 0205 Single Axle Dump Truck

Table 8 presents basic trend information related to dump truck fleet size and usage over the 2006-2009 time periods. In general, the fleet has grown from 837 vehicles in 2006 to 1038 in 2009. Total miles driven by this fleet ranged from 9.1 million in 2006 to 6.39 million miles in

2009 with the average miles per vehicle per year varying from a high of 10,854 miles in 2006 to a low 6,161 in 2009. Average utilization has been consistent over 2006-2008 as the fleet increased in size with the exception of the budget crisis in 2009.

Table 8 Single Axle Dump Truck Fleet Size and Use Trends

	2006	2007	2008	2009
Average Miles	10,854	8,068	8,278	6,161
Units	837	951	1019	1038
Total Miles	9,084,838	7,672,247	8,435,362	6,394,725
Average utilization	0.43	0.44	0.45	0.28
Average rented hours	816	751	780	558
Average available hours	1975	1849	1929	2003

Figure 6 shows the overall utilization of class 0205 across the four years of study data and indicates that 30% (1170) of the vehicles had annual utilizations of 20% or less and 58% (1086+1170) were 40% or less.

As noted for class 0201, 2009 was a year of budget curtailment so 2008 is shown in Figure 7 as a representative year to reflect the utilization levels of current operational practices and manpower levels for the 0205 dump trucks. Similar to the four year utilization levels shown in Figure 6, 27% of the units were utilized less than 20% and 52% were utilized less than 40%. Figure 8 shows the distribution of miles driven by the 0205 vehicles in 2008. In general, 28% of the units were driven less than 4,000 miles and 40% were driven less than 6,000 miles.

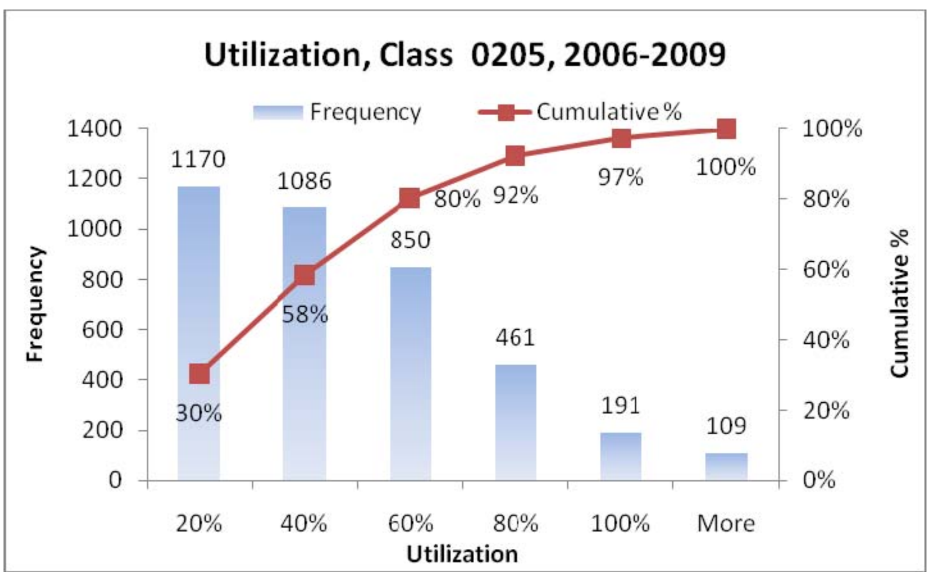

Figure 6 Utilization, Class 0205 Single Axle Dump Trucks, 2006-2009

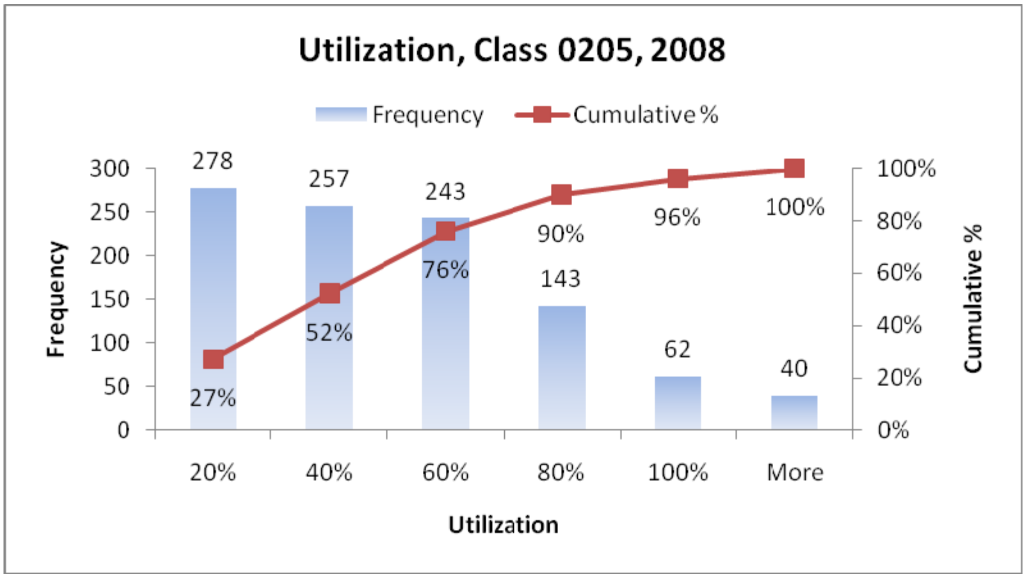

Figure 7 Utilization, Class 0205 Single Axle Dump Trucks, 2008

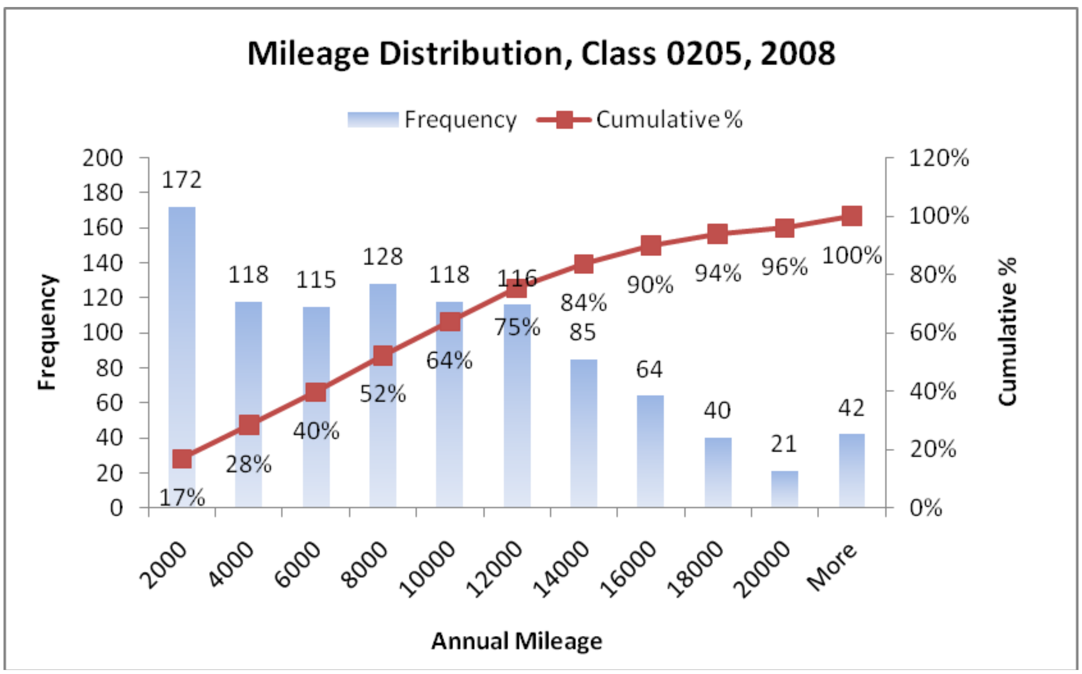

Figure 8 Mileage Distribution, 0205 Dump Truck, 2008

2.2.1 Class 0205 Dump Truck Utilization by Division and Region

Tables 9 and 10 present utilization and average miles by division.[2] In Table 8, division 6 had an exceptionally small average of available hours (1,295) and this resulted in an unrealistic average annual utilization. (It appears a large number of vehicles may have been left on repair status although available for use, thus artificially reducing the available hours.) Ignoring Division 6,

[2] Interpretation and development of these tables was discussed in relation to Class 0201.

utilization varies from a high of 54% for Division 1 to a low of 28% for Division 12. Overlap of the brackets in Table 9 indicates no obvious pattern of utilization differences between divisions. On the other hand, Table 10 does show a number of statistically different annual miles averages. For example, division 3 and 5 are different at the 95% confidence level.

Table 11 and 12 present 2008 utilization and annual miles averages for the three regions and show and shows the mountain region was significantly lower in the both utilization and miles than in the coastal or piedmont region. The coastal divisions had the highest average annual miles and the piedmont region had the highest utilization (however division 6 is included in this data).

Table 9 Single Axle Dump Truck Utilization by Division, 2008

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Div         N      Mean    St Dev  ----------+---------+---------+------
 1         91    0.5430    0.3389          (--*-)
 2         12    0.3450    0.2324  (------*------)
 3         52    0.4025    0.2289       (--*--)
 4         27    0.4167    0.3257      (---*----)
 5         96    0.3614    0.2512       (-*--)
 6         50    1.4176    2.3557                           (--*---)
 7        136    0.4158    0.2768        (-*-)
 8         68    0.5121    0.2097         (--*--)
 9         53    0.3596    0.2205      (--*--)
10         50    0.4310    0.1981       (---*--)
11        106    0.3598    0.2126       (-*-)
12         81    0.2858    0.3727     (--*-)
13         95    0.3301    0.2276      (--*-)
14         89    0.4694    0.3338         (-*--)
                                   ----------+---------+---------+------
Pooled St Dev =   0.5876                   0.50      1.00      1.50
```

Table 10 Single Axle Dump Truck Average Annual Miles by Division, 2008

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Div         N      Mean    St Dev  -------+---------+---------+---------
 1         91     11948      5928                         (---*--)
 2         12      8309      5995       (---------*---------)
 3         52     10453      6221                   (----*----)
 4         27      9094      7109             (-----*------)
 5         96      6638      4673        (--*---)
 6         48     13374      6889                             (----*----)
 7        136      6904      5060         (--*--)
 8         68     13615      5655                              (---*----)
 9         53      6938      4755       (----*----)
10         50      7701      4170          (----*----)
11        106      8287      4535             (---*--)
12         80      5313      4049   (---*---)
13         94      6499      6442       (---*--)
14         89      7263      4589          (--*---)
                                   -------+---------+---------+---------
Pooled St Dev =     5318                1000      9000     12000
```

Table 11 Single Axle Dump Truck Annual Utilization by Region, 2008

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N     Mean    St Dev   ---+---------+---------+---------+---
Coastal   182   0.4710    0.3096              (----------*----------)
Mountain  371   0.3623    0.2947   (-------*-------)
Piedmont  453   0.5244    0.8693                        (-------*------)
                                   ---+---------+---------+---------+---
Pooled St Dev =   0.6244            0.320     0.400     0.480     0.560
```

Table 12 Single Axle Dump Truck Annual Miles by Region, 2008

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N     Mean     St Dev  --------+---------+---------+--------
Coastal   182    10858      6274                           (----*-----)
Mountain  369     6940      5107   (---*---)
Piedmont  451     8640      5904               (---*--)
                                   --------+---------+---------+--------
Pooled St Dev =     5696                 7500      9000     10500
```

2.2.2 Age Trend – 0205 Dump Trucks

Table 12 summarizes trends on age of the 0205 truck over the 2006-09 data period. It demonstrates an increase in the mean age of the fleet, the median age (50% older and 50% younger) along with an increase in units over ten years old from 47 (about 5% of the fleet) to 363 (about 26% of the fleet).

Table 13 Age Trends for Class 0205 Dump Truck

	2006	2007	2008	2009
Mean age(years)	6.60	6.76	7.30	8.07
Median age (years)	6.33	7.08	7.50	8.42
% fleet < 10 years	79%	76%	71%	72%
Count > 10 years	178	225	295	291

2.2.3 Summary- Utilization of 0205 Dump Trucks

Similar to class 0201, we explored additional information on the units utilized less than 20% and found 39 units were less than one year old as noted in Figure 9. Based on the data presented in this section, we recommend reduction of the fleet by the 239 units utilized less than 20% (278-39 = 239). Similarly, we recommend a spare / pool use category consisting of the units utilized between 20% and 40% or 257 units. By redistributing the utilization hours and miles of the low utilization units, it is possible to achieve a composite utilization above 60%, an average above 75% for day to day use units, and over 35% for the spare or pool group. Table 14 summarizes this plan using 2008 data.

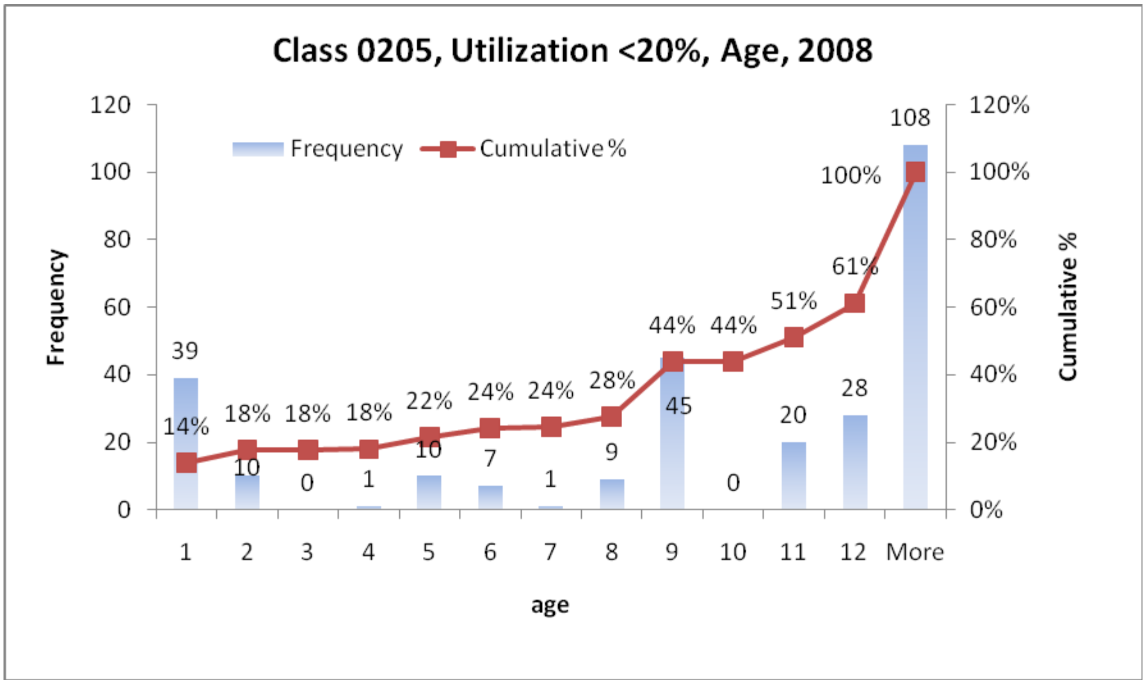

Figure 9 Age Distribution of Class 0205, Utilization < 20%

Table 14 Proposed Class 0205 Fleet Composition

	Units	% Fleet	Average Util.	Total Miles	Average Miles
Utilization > 40% (day to day operation	486	65%	0.73	6,000,718	12,347
Utilization 20%-40% (spare, pool, or sporadic use)	258	35%	0.30	1,807,886	7,007
	744	Composite Util. =	0.58		

Although likely understated for the SAP data entry reasons noted in the 0201 discussion, in general, single axle dump truck utilization is negatively impacted by a number of other organizational issues mentioned previously such as reduced NCDOT personnel levels, inconsistent availability of manpower (such as inmates for highway clean up), and the changing nature of the mission at the division level. A complicating factor is that a number of divisions, in the mountain region in particular, maintain trucks for contingency in snow response. In this effort to reduce the fleet and increase utilization, it will be important to methodically examine the following issues:

- Explore the use of rental trucks (with or without) operators to address tasks which are seasonal or require manpower which may not be consistently available.
- If rental trucks are determined to be insufficient for snow or emergency services, identify the NCDOT trucks required for this purpose and consider establishing a third utilization category for this class as discussed above.

2.3 Class 0206 Flat Bed and Miscellaneous

Figure 10 presents utilization for the 2006-2009 periods and indicate that 34% of the vehicles (798) had utilization less than 20%. Figure 11 shows 2008 utilization and presents a similar trend with 31% of the units (193) utilized less than 20%.

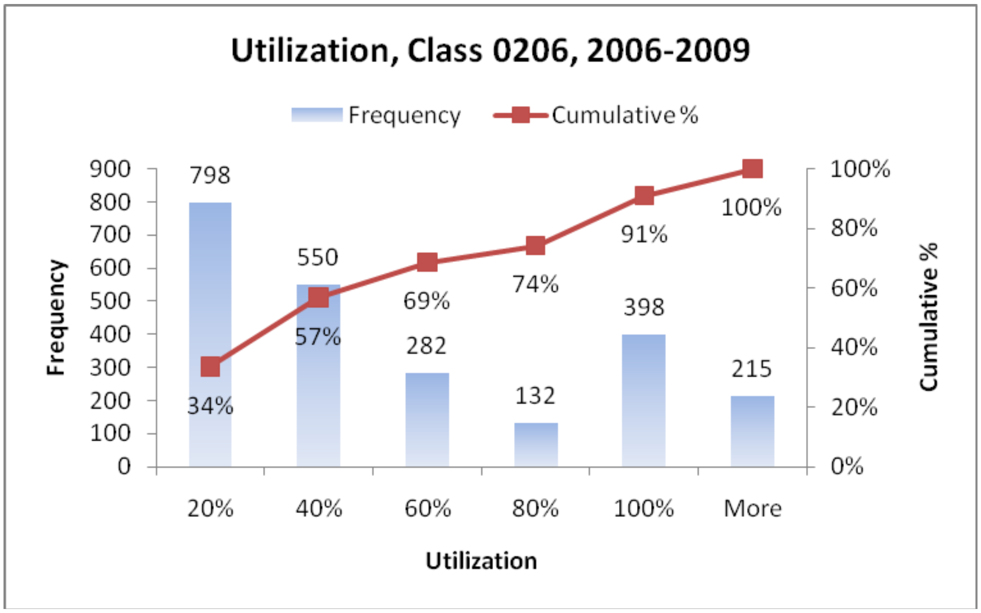

Figure 10 Utilization, Class 0206, 2006-2009

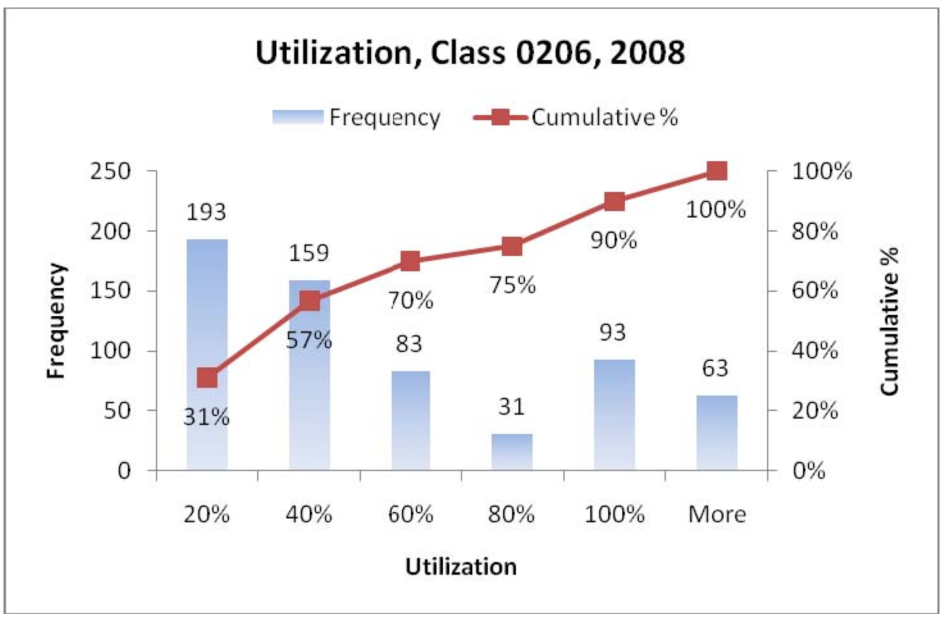

Figure 11 Utilization, Class 0206, 2008

Class 0206 is difficult to characterize since it is composed of a wide range of special purpose units in addition to one large group, flat bed trucks (truck2). Table 15 summarizes descriptive information on the items in this category based on SAP designation and the functional description. A report recommendation developed by the project team is that segmenting this class should be considered for consistency of data analysis. The primary reason for this is that many of these sub class items are necessary for operational performance and serve a special purpose which cannot be easily obtained from rental or other sources.

Table 16 summarizes operational data for the 0206 subclasses. The "other" category contains GASPCH, GAUGER, GCRAN1, GMCHST, GPAIN2, and GTRSV. Table 16 also shows the largest category is the flat bed "Truck2" designation. Table 17 shows the current utilization levels and numbers in the fleet. Utilizations vary from 90% for fuel trucks to 14% for a paint truck and 17% for the auger sub class. The utilization for the 359 units in the truck2 group was 37% in 2008. Table 18 presents overall utilization of class 0206 by division. Discounting division 6, utilization ranges from 38% for division 10 to 58% for division 9.

Table 19 specifically examines data on truck2 and shows a fleet which has grown from 306 in 2006 to 380 in 2009. During the 2006-2008 intervals, utilization was generally flat but mileage per truck declined since total mileage during this time did not change. Figure 12 presents the 2008 utilization of truck 2 units for 2008 and indicates that 32% (115) had utilization less than 20%. Figure 13 presents the mileage distribution of truck 2 units in 2008 and indicates that 20% drove less than 2,000 miles.

Table 15 Categories and Descriptions, Class 0206

SAP Designation	Functional Description
GAER1A, GAER1C, GAER1D, GAERWP	Aerial bucket or platform truck
GASPCH	Asphalt Patch
GAUGER	auger
GCRAN1	Crane
GDIST1 GDIST2 GDISTR	Asphalt distributor
GFUELT	Fuel / lube
GMCHST	Mechanical repair
GPAIN2	Line painting
GSEEDR	Seeder
GSPRY1	Spray
GTOWPK	Tow
GTRFSV	Traffic service
TRUCK2	Flat Bed

Table 16 Summary of Class 0206 Sub Category Data

GAER	2006	2007	2008	2009
Average Miles/ year	14,561	11,074	9,312	8,595
Units in the Fleet	47	48	49	49
Total miles	684,355	531,573	456,307	421,144
GDIST				
Average Miles/ year	4,507	3,848	3,737	2,228
Units in the Fleet	22	23	27	29
Total miles	99,143	88,510	100,907	64,623
GFUELT				
Average Miles/ year	10,189	7,340	6,842	5,280
Units in the Fleet	92	102	109	109
Total miles	937,383	748,681	745,774	575,543
GSEEDR				
Average Miles/ year	4,043	4,535	4,042	3,245
Units in the Fleet	15	15	23	23
Total miles	60,642	68,029	92,977	74,624
GSPRY1				
Average Miles/ year	5,074	5,285	5,313	3,242
Units in the Fleet	18	17	20	21
Total miles	91,326	89,847	106,250	68,090
GTOWPK				
Average Miles/ year	654	442	427	348
Units in the Fleet	18	18	17	18
Total miles	11,775	7,948	7,254	6,265
GTRUCK2				
Average Miles/ year	7,436	6,108	5,973	4,189
Units in the Fleet	304	339	356	379
Total miles	2,260,661	2,070,645	2,126,471	1,587,476
"OTHER"				
Average Miles/ year	9,625	8,178	8,001	7,579
Units in the Fleet	9	9	11	11
Total miles	86,626	73,600	88,006	83,364

Table 17 2008 Utilization for Class 0206 Sub Category

```
                                   Individual 95% CIs For Mean Based on Pooled StDev
Level     N    Mean   StDev     -+---------+---------+---------+--------
GAER1A   19  0.6601  0.3856                         (--*--)
GAER1C   23  0.3547  0.4256                     (-*-)
GAER1D    1  0.0273       *     (----------*-----------)
GAERWP    8  0.0586  0.0584             (---*---)
GASPCH    1  0.0000       *     (----------*----------)
GAUGER    3  0.1707  0.1972            (------*-----)
GCRAN1    1  0.9967       *                      (-----------*----------)
GDIST1   13  0.2718  0.1564                  (---*--)
GDIST2    2  0.2967  0.2906              (-------*-------)
GDISTR   12  0.2613  0.1313                  (--*---)
GFUELT  110  0.9014  0.4322                                   (*)
GMCHST    5  0.5164  0.4548                     (----*----)
GPAIN2    1  0.1372       *       (----------*----------)
GSEEDR   23  0.2042  0.1269                  (-*--)
GSPRY1   21  0.1857  0.1226                  (-*--)
GTOWPK   19  0.8660  0.3583                                (-*--)
GTRFSV    1  0.4373       *            (----------*----------)
TRUCK2  359  0.3731  0.3303                       (*)
                                -+---------+---------+---------+--------
                              -0.60      0.00      0.60      1.20
Pooled StDev = 0.3417
```

Table 18 2008 Utilization for Class 0206 by Division

```
                                Individual 95% CIs For Mean Based on
                                 Pooled StDev
Div     N    Mean   StDev    -------+---------+---------+---------+--
1      43  0.4290  0.4042      (-----*-----)
2      44  0.4730  0.3659         (-----*-----)
3      40  0.5052  0.3826          (-----*------)
4      46  0.5041  0.3803          (-----*-----)
5      27  0.4815  0.3821       (-------*-------)
6      44  0.7808  0.7627                           (-----*-----)
7      36  0.4242  0.3607      (-----*------)
8      63  0.4042  0.3521      (----*----)
9      33  0.5793  0.3636             (------*------)
10     44  0.3788  0.3132    (-----*-----)
11     68  0.4102  0.3504       (----*---)
12     35  0.4375  0.3764      (------*------)
13     51  0.4079  0.3534      (----*-----)
14     48  0.4314  0.3422       (-----*----)
                             -------+---------+---------+---------+--
                                  0.40      0.60      0.80      1.00
Pooled StDev = 0.4038
```

Table 19 Class 0206 Truck 2 Sub Category Fleet Size and Use Trends, 2006-2009

	2006	2007	2008	2009
Average miles	7436	6108	5973	4189
Units	306	343	359	380
Total Miles	2,260,661	2,070,645	2,126,471	1,587,476
Average utilization	38.7%	42.0%	37.3%	24.1%
Average rented hours	942	737	727	496
Average Available	2033	1878	1985	2039

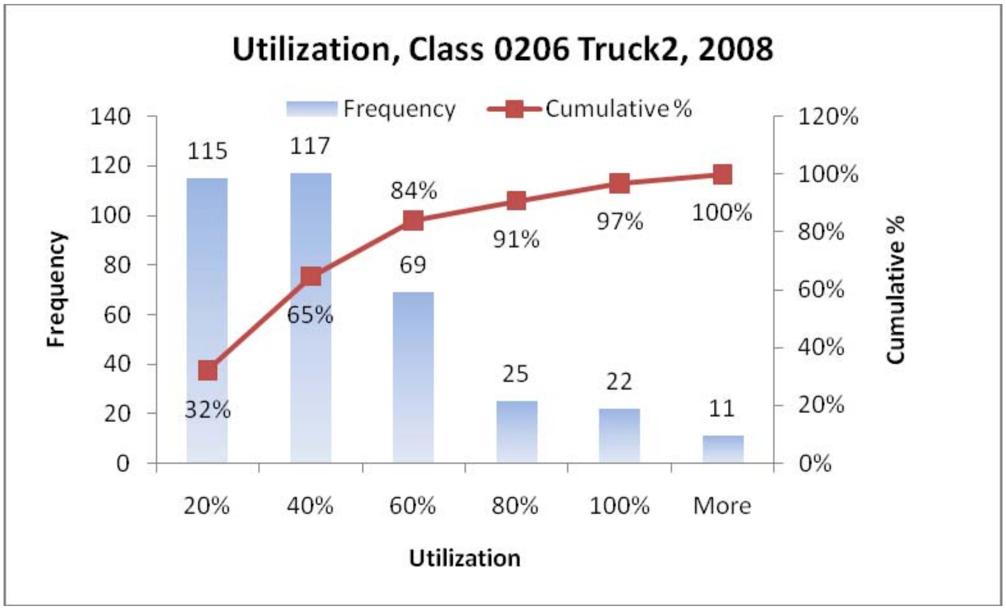

Figure 12 Utilization, Class 0206 Truck2, 2008

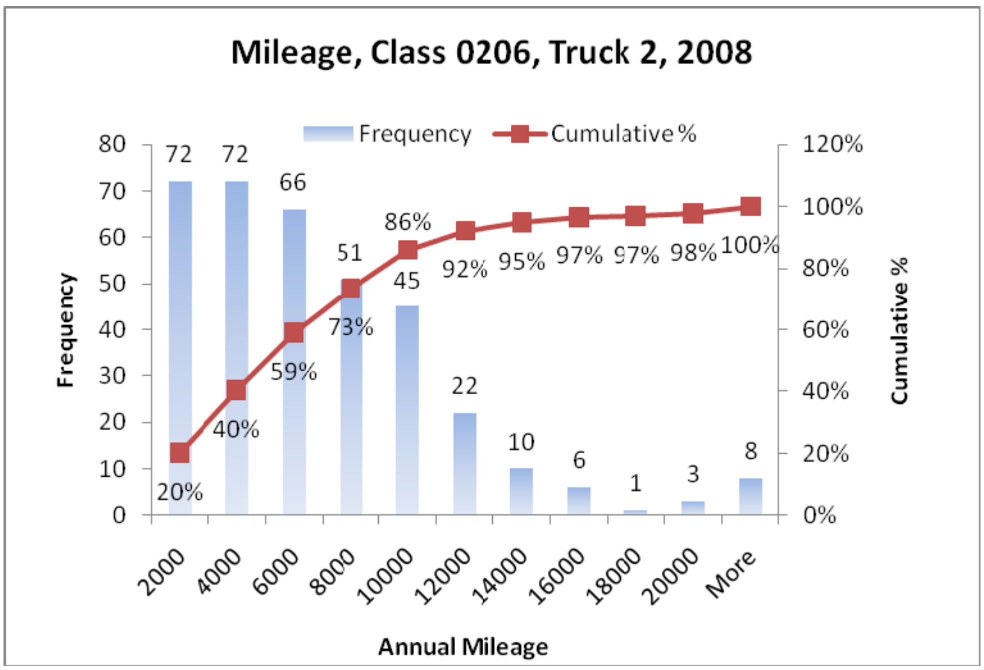

Figure 13 Mileage Distribution, Truck 2, 2008

2.3.1 Summary- Utilization of Class 0206

Class 0206 contains a wide variety of units with extremes of utilization. The flat bed truck2 is the largest individual group (359) followed by the fuel truck (GFUELT) category at 110. The remaining groups range from 23 for seeders and aerial trucks down to single digit units such as line painters. Fuel trucks had average utilization above 90% while the truck2 group had an average of 37% in 2008.

Utilization improvement recommendations for truck2 units mirrors class 0205 in several ways. First, Figure 14 indicates that 12 of the 115 units utilized less than 20% in 2008 were new units. Consequently we recommend reduction of this fleet by 103 units. Similarly per the summary in Table 20, we recommend a spare / pool use category consisting of the units utilized between 20% and 40% or 117 units and a day to day operational group of 127 units. By redistributing the utilization hours and miles of the low utilization units, it is possible to achieve a composite utilization of 55%, a utilization average above of 75%% for day to day use units, and 35% for the spare or pool group. Table 20 summarizes this plan using 2008 data.

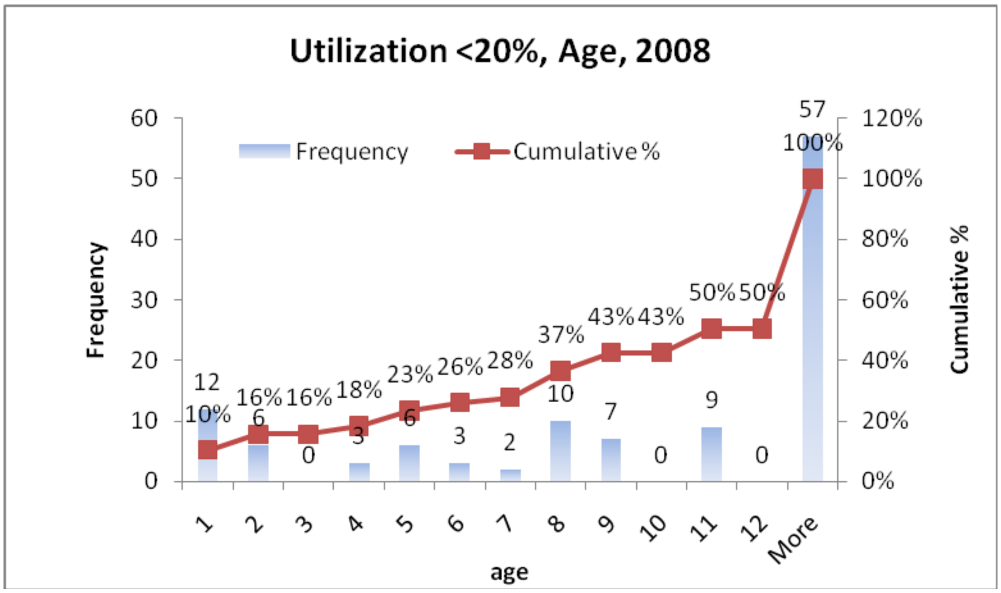

Figure 14 Age of Class 0206 Truck2, Utilization < 20%, 2008

Table 20 Proposed Class 0206, Truck2 Fleet Composition

	Units	**% Fleet**	**Average Util.**	**Total Miles**	**Average Miles**
Utilization > 40% (day to day operation	127	52%	0.69	1,138,147	8,962
Utilization 20%-40% (spare, pool, or sporadic use)	117	48%	0.30	708,054	6,052
	244	Composite Util. =	0.51		

Relative to utilization goals for other the sixteen categories in class 0206, we recommend that the seasonal aspect of their usage be considered in the target. For example, the average utilization of the 23 GSEEDR seeding units was 20% in 2008. Considering their seasonal application time window is six months, this is equivalent to a 40% utilization level and this may be appropriate as a target.

2.4 Class 0314 Backhoe-Loader Overview

Table 21 presents trend information related to backhoe-loader fleet size and usage over the 2006-2009 time periods. In general, the fleet has grown from 214 units in 2006 to 297 in 2009 and the average annual operating hours decreased from 531 hours in 2006 to 299 in 2009. Total hours usage by this fleet generally was consistent for the 2006-2008 years with a high of 104,225 hours in 2006 and a low of 88,320 in the economically difficult year 2009. In the case of off road equipment such as this unit, records of use are maintained only in hours of operation. Average annual utilization declined slightly from 52% in 2006 to 48% in 2007-2008. Utilization in 2009 fell to 32% due to budget issues.

Table 21 Backhoe / Loader Fleet Size and Use Trends 2006-2009

	2006	2007	2008	2009
Average operating hours	531	336	378	299
Units in the Fleet	214	274	275	297
Total operating hours	104,225	92,086	103,817	88,320
Average utilization	0.52	0.48	0.48	0.32
Average rented hours	1136	762	808	614
Average available hours	1908	1782	1858	1946

Figures 15 and 16 show the distribution of annual utilization for the 2006- 2009 periods and for 2008, a typical operating year. In general, the results are consistent with 20-25% of the units utilized less than 20%. Figure 17 presents the distribution of operating hours for 2008 and shows 10% of the units (25) were operated less than 100 hours and 23% (25+39= 64) were operated less than 200 hours.

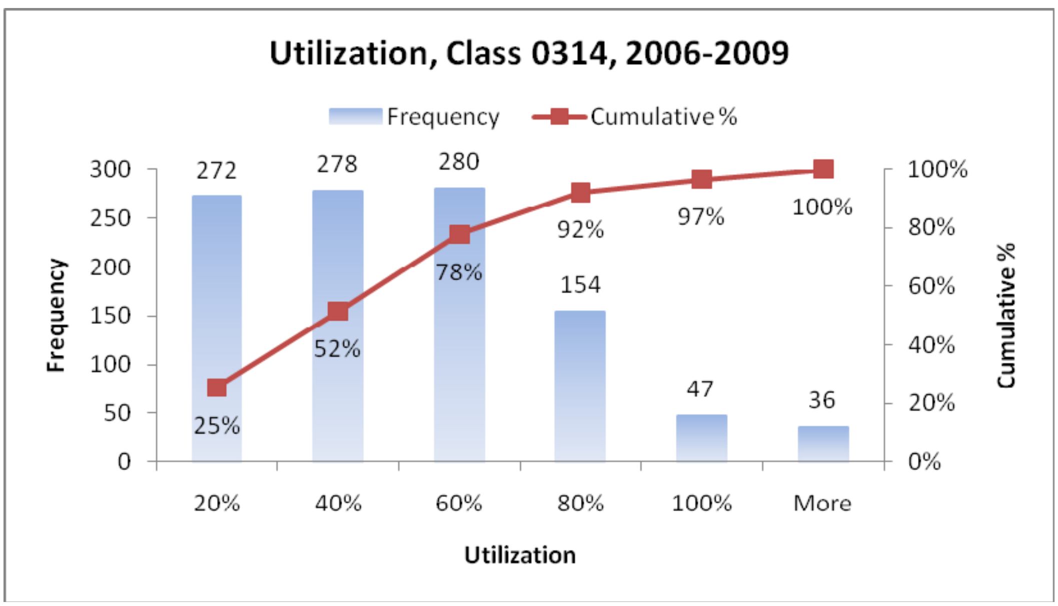

Figure 15 Overall Utilization, Class 0314 Loader-Backhoe, 2006-2009

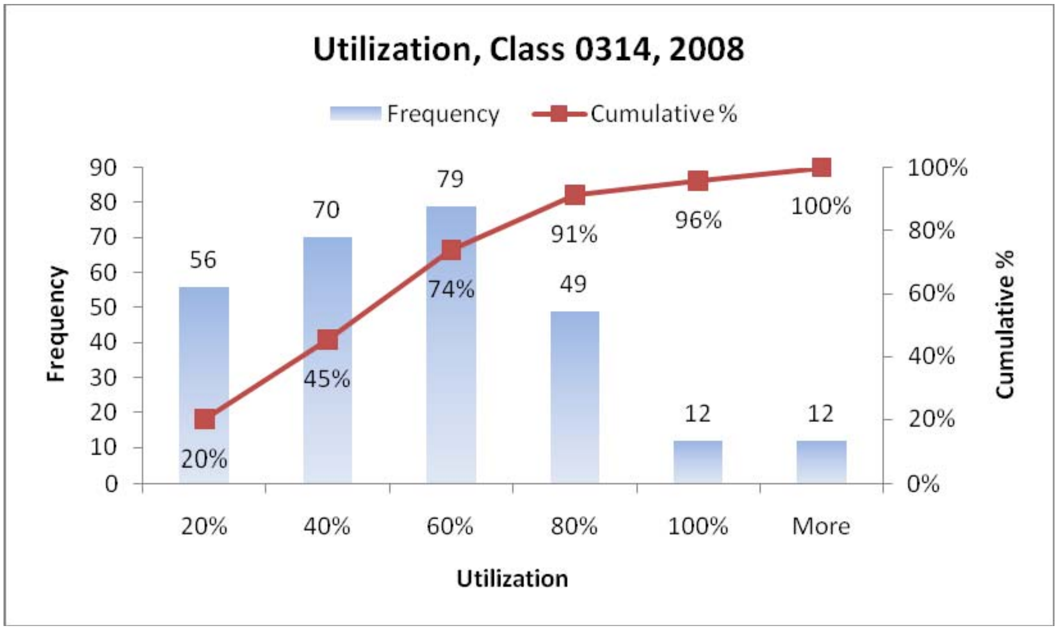

Figure 16 Utilization, Class 0314 Loader-Backhoe, 2009

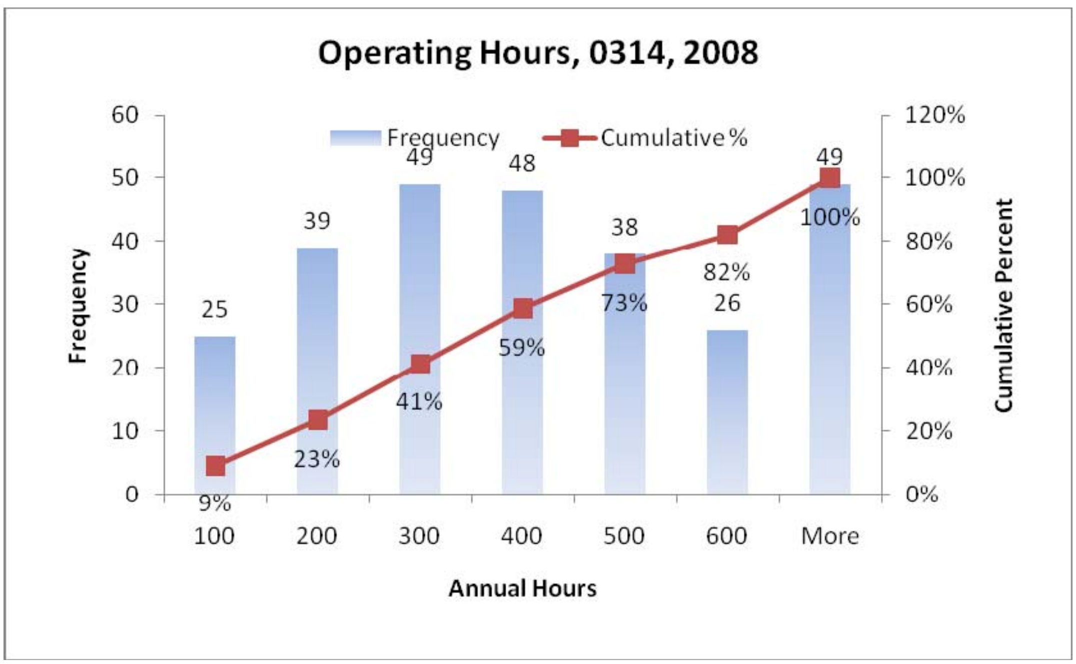

Figure 17 Operating Hours, Class 0314 Loader-Backhoe, 2008

Table 22 and 23 present average annual utilization values and average operating hours by division for 2008. Once again, as in previous classes, division 6 data is overstated due to low available hours based on data entry details. In general, utilization in Table 22 ranges from a high of 60% for division 8 to a low of 28% for division 2. Three divisions were very near 50%. Utilization in the mountain divisions was generally lower in the 36%-38% range. Operating hours in Table 23 shows a high of 497 in division 1 to a low of 227 in division 13.

Table 22 Backhoe/Loader Utilization by Division- 2008

```
                           Individual 95% CIs For Mean Based on Pooled StDev
Div     N    Mean   StDev    +---------+---------+---------+---------
1      23  0.4953  0.4496            (--*---)
2       7  0.2813  0.1598    (------*------)
3      16  0.5124  0.2810           (----*---)
4      18  0.4841  0.2175           (---*---)
5      14  0.3834  0.2309        (----*---)
6      14  1.2851  0.9707                              (----*----)
7      28  0.4453  0.2663           (--*---)
8      24  0.6005  0.5603              (---*---)
9      23  0.3934  0.2006         (---*---)
10     16  0.4884  0.2033           (---*----)
11     23  0.3717  0.2146        (---*---)
12     20  0.3643  0.1983        (---*---)
13     26  0.3640  0.2419        (---*---)
14     25  0.3877  0.3698         (---*--)
                             +---------+---------+---------+---------
                           0.00      0.40      0.80      1.20
Pooled StDev = 0.3734
```

Table 23 Backhoe/Loader Average Annual Operating Hours by Division-2008 Data

```
                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Div     N   Mean  StDev  --------+---------+---------+---------+-
1      23  497.8  269.3                        (------*-------)
2       7  380.7  226.6        (-------------*------------)
3      16  427.8  244.8                 (--------*-------)
4      18  474.3  236.6                     (--------*-------)
5      14  365.9  209.6           (--------*---------)
6      13  424.5  169.7                (--------*---------)
7      27  366.0  251.5              (------*-----)
8      24  433.4  178.9                   (------*------)
9      23  438.4  214.4                   (-------*------)
10     16  354.1  183.7           (--------*-------)
11     23  345.5  251.7           (-------*------)
12     19  394.4  228.2               (-------*-------)
13     26  227.5  142.8  (------*------)
14     25  251.7  166.6    (------*------)
                         --------+---------+---------+---------+-
                               240       360       480       600
Pooled StDev = 215.5
```

Table 24 presents regional utilization and shows the mountain region as the lowest. Coastal and piedmont are generally equal if the impact of division 6 is removed from the piedmont group. Relative to operating hours, the coastal region is significantly higher than the other two regions. Similarly, the mountain region is significantly lower than the other two regions.

Table 24 Utilization by region, 2008 Data

```
                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level      N    Mean   StDev   -+---------+---------+---------+--------
Coastal   64  0.4730  0.3306           (---------*---------)
Mountain  94  0.3722  0.2646   (-------*--------)
Piedmont 119  0.5639  0.5249                       (------*-------)
                               -+---------+---------+---------+--------
                              0.30      0.40      0.50      0.60
Pooled StDev = 0.4093
```

Table 25 Annual Operating Hours by Region, 2008 Data

```
                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level      N   Mean  StDev  ----+---------+---------+---------+-----
Coastal   64  460.9  247.3                      (-------*------)
Mountain  93  297.3  206.4  (-----*------)
Piedmont 117  398.9  206.9                (-----*-----)
                            ----+---------+---------+---------+-----
                              280       350       420       490
Pooled StDev = 216.8
```

2.4.1 Fleet Age- Backhoe Loader

Table 26 summarizes trends on age of the class 0314 fleet for the 2006-09 data period and shows an increase in the mean age of the fleet and the number of units over 10 years old. The growth of this fleet during this period mitigated this aging trend. Figure 15 more clearly illustrates the aging issue for this class. Due to inconsistent purchase patterns, 71 units of the 2009 fleet of 297 are 13 years old or more.

Table 26 Age Trends of Class 0314

	2006	2007	2008	2009
Mean age(years)	6.1	5.6	6.5	7.1
Median age (years)	6.9	6.7	6.7	7.0
% fleet < =10 years	67%	74%	75%	67%
Count > 10 years	71	71	69	100

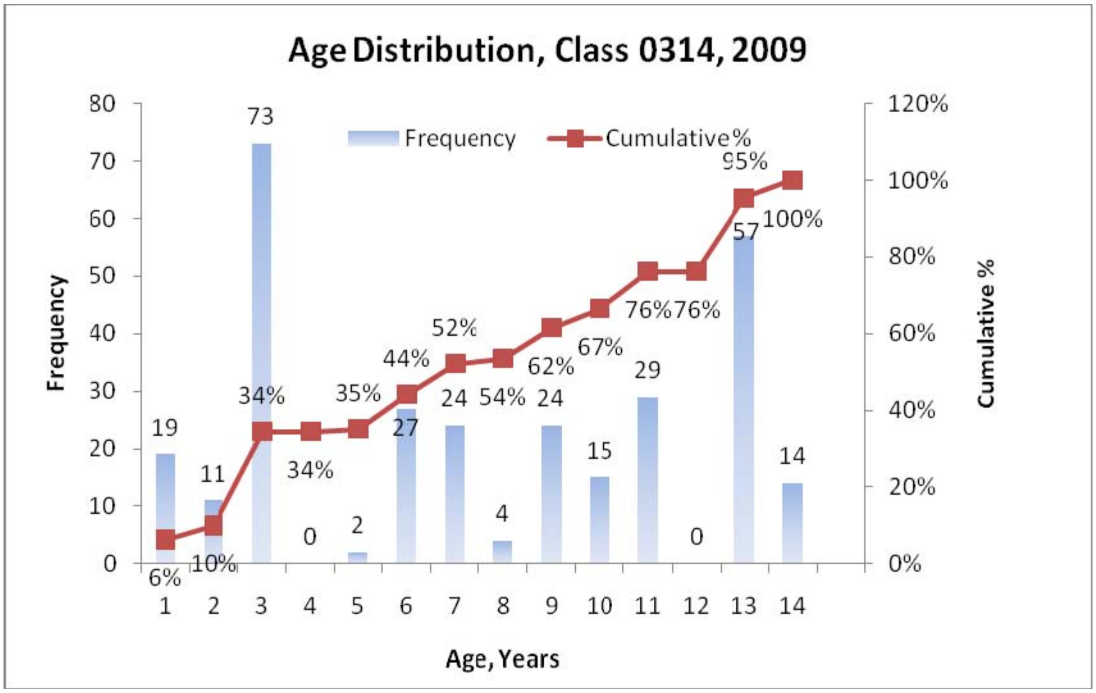

Figure 18 Age Distribution, Class 0314 Loader-Backhoe, 2009

2.4.2 Summary- Utilization of 0314 Loader-Backhoe

The data in this section indicates there were 56 units (20% of the fleet) utilized less than 20% and 64 (23% of the fleet) operated less than 200 hours in 2008. Nearly 25% of the class 0314 fleet was at least 13 years old at the end of 2009. Based on this and the other data presented in this section, Table 27 presents a proposal for 0314 fleet composition. It recommends reduction of 56 units which are utilized less than 20% and establishing day to day and spare/ pool categories. Based on 2008 data, the reallocation of the hours of use to the remaining fleet should produce a composite utilization over 60%, day to day utilization over 75% and spare / pool utilization of 35%.

Table 27 Proposed Class 0314 Fleet Composition

	Units	% Fleet	Average Util.	Total Hours	Average Hours
Utilization > 40% (day to day operation	152	68%	0.73	73,310	482
Utilization 20%-40% (spare, pool, or sporadic use)	70	32%	0.30	20,640	295
	222	Composite Util. =	0.57	93,950	

Since the 0314 loader-backhoe is a flexible unit capable of a variety of operational use, it will be particularly important to methodically examine the availability of pool and rental equipment as the currently underutilized and aged equipment is reduced. For example, a recommendation from discussions with the divisions identified use of rental units (with or without) operators to address tasks which are seasonal or require manpower which may not be consistently available.

2.5 Class 0900 Motor Grader Overview

Table 28 summarizes use and fleet information for the 0900 motor grader over the 2006-2009 periods. The number of units increased from 373 in 2006 to 434 in 2009. Utilization remained flat in the 38% to 39% range during regular operating years (2006-2008). During the 2006-2008 period, total annual operating hours declined, average operating hours per unit, average rented hours, and average available hours declined. Weather is a factor in utilization variation of these units since they are heavily used in major snow events.

Table 28 Motor Grader Fleet Size and Use Trends, 2006-2009

	2006	2007	2008	2009
Average annual operating hours	540	411	412	298
Units	373	429	436	434
Total annual operating hours	198,572	174,082	178,954	127,710
Average utilization	38%	42%	39%	23%
Average rented hours	814	603	627	435
Average available hours	1896	1732	1809	1953

Figure 19 shows the utilization information over the 2006-2009 periods and indicates 37% of the units were utilized less than 20%. Figure 20 contains utilization data for the 2008 operating year and shows a similar pattern on the low utilization end with 32% of the units (141) with less than 20% utilization. Figure 21 presents operating hours for 2008 and indicates that 52 units (12%) had less than 100 hours of use and 113 (26%) had less than 200 hours.

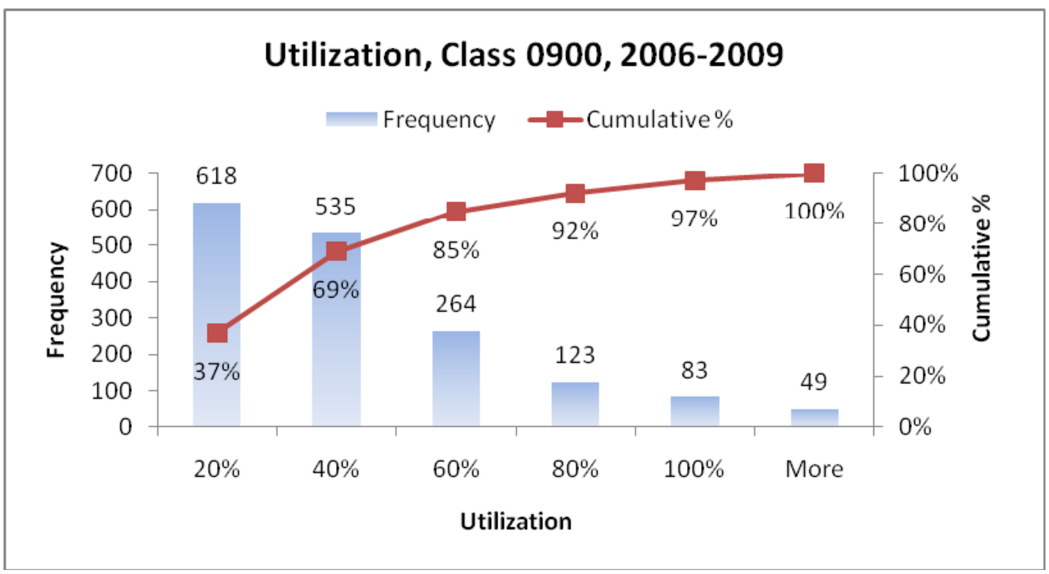

Figure 19 Utilization, Class 0900 Grader, 2006-2009

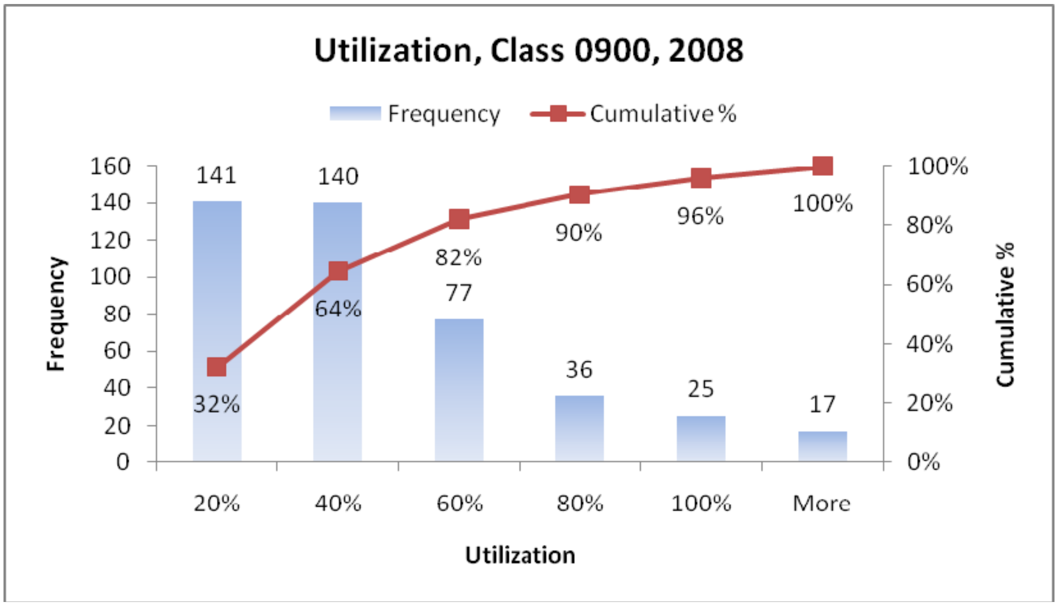

Figure 20 Utilization, Class 0900 Grader, 2008

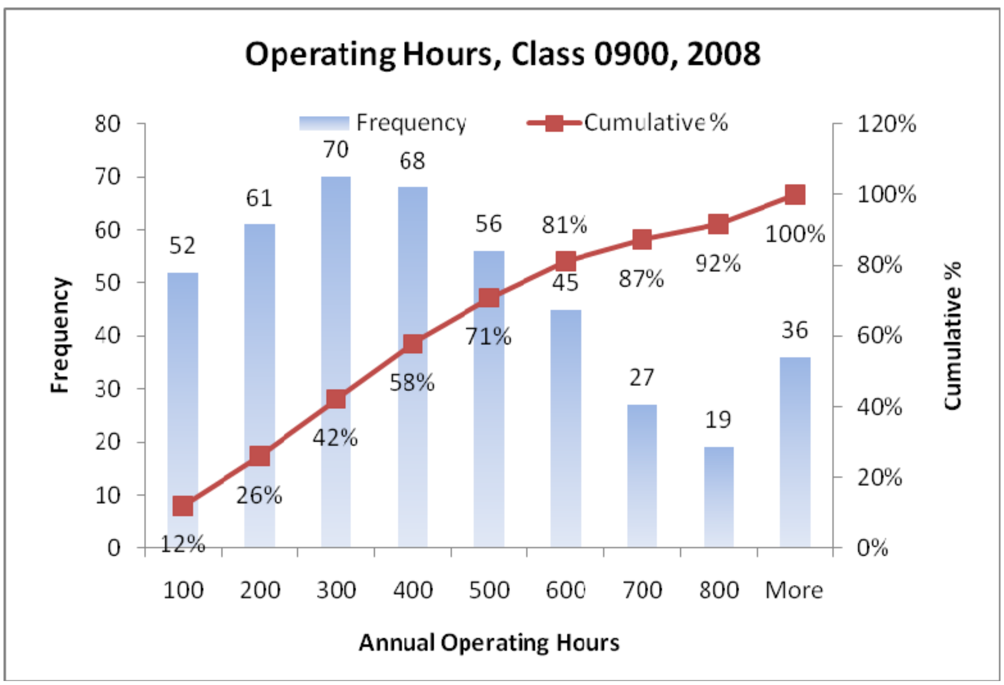

Figure 21 Operating Hours, Class 0900 Grader, 2008

Table 29 presents average annual utilization for 2008 by division. Excluding division 6, utilization ranged from highs of 55% in division 14 and 49% in division 3 to lows of 21% in divisions 7 and 13. Table 30 presents the average operating hours in 2008 by division and shows a high of 489 for division 2 (excluding division 6) and a low of 244 for division 7.

Table 29 Motor Grader Utilization by Division, 2008

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled St Dev
Div         N      Mean    St Dev   --------+---------+---------+--------
 1         39    0.3359    0.2027        (--*--)
 2         26    0.3619    0.2395        (--*---)
 3         18    0.4878    0.3304           (---*---)
 4         28    0.3382    0.2624       (---*--)
 5         32    0.2391    0.1949     (--*--)
 6         31    1.2132    0.8938                                (---*--)
 7         42    0.2133    0.1705    (--*--)
 8         35    0.4131    0.2502          (--*--)
 9         26    0.2408    0.1632    (---*--)
10         25    0.2956    0.1153      (--*---)
11         41    0.3663    0.2429         (-*--)
12         30    0.2077    0.1648    (--*--)
13         38    0.3332    0.2650        (--*--)
14         25    0.5476    0.3834             (---*--)
                                    --------+---------+---------+--------
Pooled St Dev =   0.3281                  0.35      0.70      1.05
```

Table 30 Motor Grader Annual Operating Hours by Division, 2008

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled St Dev
Div         N      Mean     St Dev   --------+---------+---------+--------
 1         39     491.0     251.8            (----*-----)
 2         26     489.3     351.0          (------*------)
 3         18     546.0     373.7           (-------*-------)
 4         28     396.9     288.0        (-----*------)
 5         32     303.4     218.5     (-----*-----)
 6         31     861.7    1788.5                       (------*-----)
 7         40     244.0     179.7    (----*-----)
 8         35     479.5     271.8           (-----*-----)
 9         26     322.0     205.3     (------*------)
10         25     277.0     120.8   (------*------)
11         41     434.5     266.7          (----*-----)
12         30     262.4     180.4   (------*-----)
13         38     319.0     194.5      (-----*----)
14         25     403.0     222.1       (------*------)
                                    --------+---------+---------+--------
Pooled St Dev =    532.5                   300       600       900
```

Table 31 shows regional utilization for the motor graders and does not indicate a statistically significant difference between the three areas of the state. Table 32 presents the average for operating hours for 2008 and once again does not demonstrate a significant difference in the regions.

Table 31 Motor Grader Utilization by Region, 2008 Data

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N     Mean    StDev    ---+---------+---------+---------+---
Coastal   111   0.3672   0.2529      (-----------*------------)
Mountain  134   0.3552   0.2860     (----------*-----------)
Piedmont  191   0.4310   0.5281                  (---------*--------)
                                   ---+---------+---------+---------+---
Pooled StDev =   0.4047             0.300     0.360     0.420     0.480
```

Table 32 Grader Annual Operating Hours by Region, 2008 Data

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N     Mean    StDev    ----+---------+---------+---------+--
Coastal   111    475.8    307.2               (----------*---------)
Mountain  134    357.3    229.3    (---------*--------)
Piedmont  189    414.1    769.1            (------*-------)
                                   ----+---------+---------+---------+--
Pooled StDev =    546.2                 300       400       500       600
```

2.5.1 Fleet Age – Motor Graders

Table 33 shows the age data of the current fleet of motor graders and presents a consistent picture of an aging fleet. Over the four years of the study data, the average age increased from 8.2 to 9.8 years, the median age increased from 8.6 to 9.0 years, the percent of the fleet less than ten years old decreased from 69% to 51%, and the number over ten years old increased from 114 to 211, approximately half of the 2009 fleet.

Table 33 Age Trends for Class 0900 Grader

	2006	2007	2008	2009
Mean age (years)	8.2	8.1	8.9	9.8
Median age (years)	8.6	7.0	8.0	9.0
% fleet < =10 years	0.69	0.73	0.51	0.51
Count > 10 years	114	115	213	211

Figure 22 provides a more detailed look at the age of the 0900 fleet. About 23% of the fleet (99 units) was 12 years old in 2009 and 26% is 14 or more years old (112 units). Significant investment will be needed to modernize this fleet in the near future. Considering the cost of one motor grader is equivalent to three dump trucks, this will have a significant impact on the replacement budget.

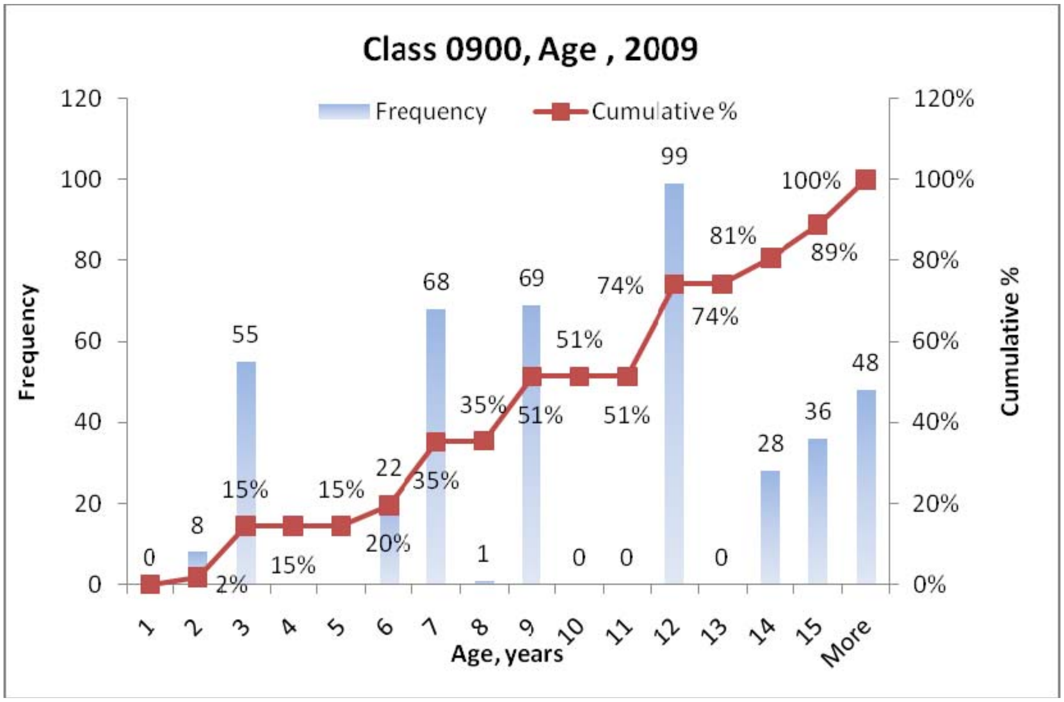

Figure 22 Age Distribution, Class 0900 Motor Grader, 2009

2.5.2 Summary- Utilization of 0900 Motor Grader

Data examined in this section indicated there were 141 units (32% of the fleet) utilized less than 20% and 281 (64% of the fleet) utilized less than 40%. For average operating hours, 113 (26% of the fleet) operated less than 200 hours and 183 (42% of the fleet) operated less than 300 hours in 2008. Considering the age and replacement cost of these units, reduction of this fleet by removing the aged units with utilization less than 20% is an appropriate goal and results in a fleet of 295 units as proposed in Table 34. This fleet proposal, and redistribution of the hours supported by the underutilized units, should result in utilization of the day to day fleet over 75% and the pool fleet over 30%, with an overall composite fleet utilization over 55%.

Table 34 Proposed Class 0900 Fleet Composition

	Units	% Fleet	Average Util.	Total Hours	Average Hours
Utilization > 40% (day to day operation	155	53%	0.75	96,587	623
Utilization 20%-40% (spare, pool, or sporadic use)	140	47%	0.30	50,162	358
	295	Composite Util. =	0.53	146,749	

It will be important to methodically examine the following opportunities related to increasing utilization and fleet size reduction:

- Unpaved road repair is one of the uses of these units. As the number of unpaved miles decreases, the long term need for units in this fleet decreases.

- Several divisions have negotiated winter rental agreements for motor grader units to be available for snow removal. Cost effective rates have been realized since this is a season when many are not used by the road construction businesses.
- Use of rental units (with or without) operators to address other sporadic tasks which are seasonal or require manpower which may not be consistently available.

2.6 Class 2002 Front-end Loader Overview

Table 35 summarizes important fleet size and use information for the class 2002 front end loader over the 2006-2009 time periods. The number of units in the fleet was generally flat during the 2006-2008 periods at around 192 and utilization increased. The average available hours decreased over the 2006-2008 periods as did the average annual rental hours. The fleet increased from 2008-2009 from 193 to 216 units. This increase, coupled with the budget issues in 2009, resulted in utilization decrease to 24% for 2009.

Table 35 Front-end Loader Size and Use Trends, 2006-2009

	2006	2007	2008	2009
Average operating hours	379	301	290	221
Units in fleet	190	192	193	216
Total operating hours	72,090	57,790	55,900	47,842
Average utilization	33%	41%	37%	24%
Average rented hours	768	659	670	464
Average available hours	1961	1773	1871	1981

Figure 23 shows the distribution of annual utilization in the 2002 fleet during the 2006-2009 interval and indicates that 50% of the units had 20% or less utilization. Figure 21 presents similar data for 2008 alone and shows 46% of the fleet utilized 20% or less. Figure 22 shows the distribution of operating hours in 2008. 17% of the fleet (33 units) operated less than 100 hours and 39% (76 units) operated less than 200 hours.

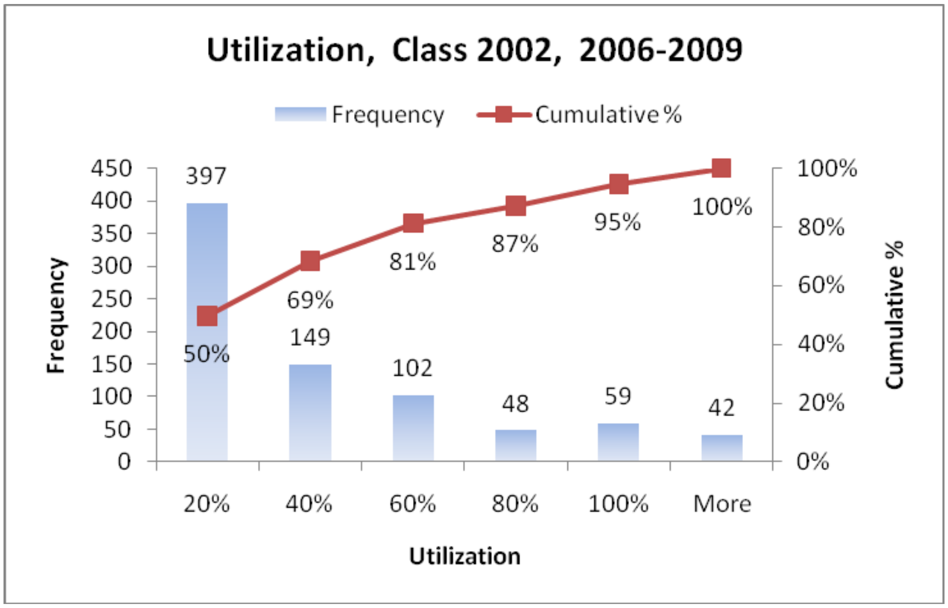

Figure 23 Utilization, Class 2002 Loader, 2006-2009

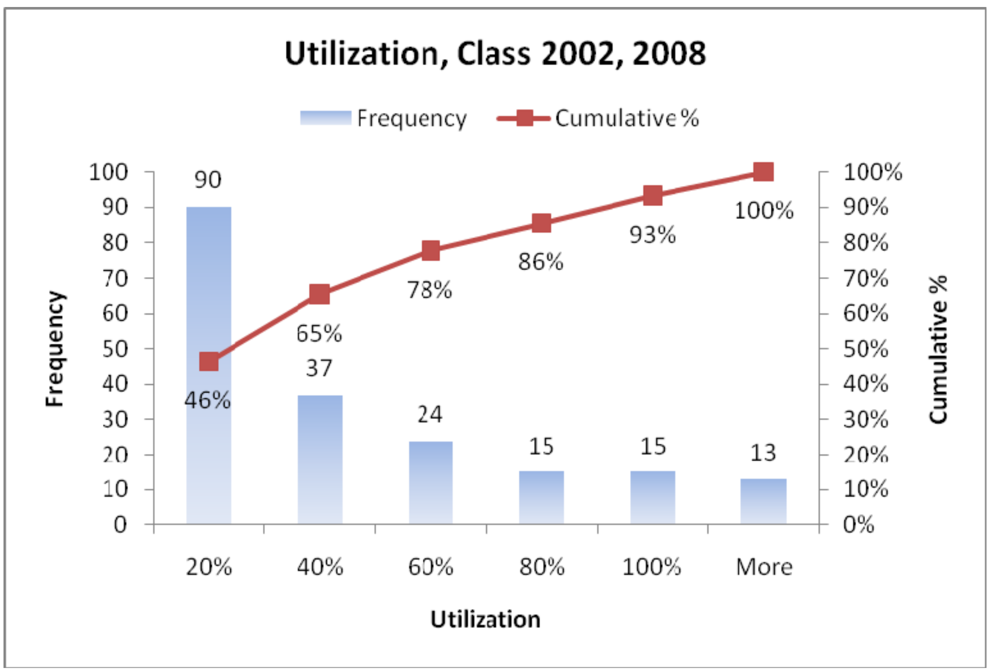

Figure 24 Utilization, Class 2002 Loader, 2008

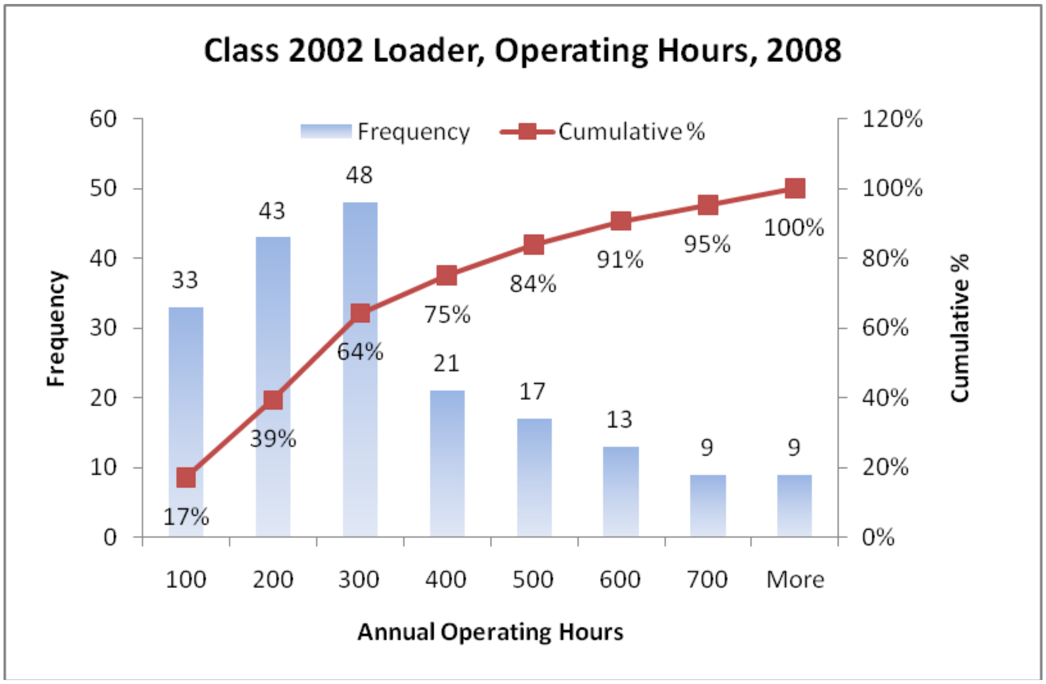

Figure 25 Operating Hours, Class 2002 Loader, 2008

Tables 36 and 37 examine average utilization and average annual operating hours by division. Table 36 shows a low utilization of 14% in division 12 and a high of 55% in division 7 (with division 6 excluded). The divisional operating hours in Table 37 show a low of 148 in division 10 and a high of 453 in division 2.

Table 36 Front-end Loader Utilization by Division- 2008

```
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
Div         N     Mean    St Dev    --+---------+---------+---------+----
 1         23   0.3122    0.2410           (---*----)
 2         15   0.2673    0.2393        (-----*-----)
 3         12   0.4117    0.4021            (------*-----)
 4         16   0.3775    0.3602            (-----*----)
 5         10   0.4480    0.3859             (------*------)
 6         16   0.7856    0.6271                         (-----*-----)
 7          9   0.5533    0.5508                (------*-------)
 8         11   0.1673    0.1825     (------*------)
 9          9   0.3022    0.2461        (-------*-------)
10         12   0.3317    0.2545          (------*------)
11         15   0.3300    0.3558           (-----*-----)
12         15   0.1380    0.1855     (-----*-----)
13         15   0.2560    0.3018        (-----*-----)
14         16   0.5044    0.3650                (-----*-----)
                                    --+---------+---------+---------+----
Pooled St Dev =   0.3538             0.00      0.30      0.60      0.90
```

Table 37 Front-end Loader Annual Operating Hours by Division-2008

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Div         N      Mean    St Dev  --------+---------+---------+--------
 1         23     352.6     234.3                  (-----*----)
 2         15     452.9     262.3                        (-----*------)
 3         12     301.0     160.0             (------*-------)
 4         16     313.8     162.5              (------*-----)
 5         10     304.0     254.7            (-------*-------)
 6         16     385.4     162.9                   (------*-----)
 7          9     307.6     249.2            (--------*-------)
 8         11     236.7      91.8        (-------*-------)
 9          9     290.8     167.0           (-------*--------)
10         12     147.9      97.2  (-------*------)
11         15     334.7     280.4                (-----*------)
12         15     244.3     231.7          (-----*------)
13         14     150.8      90.9   (------*------)
14         16     162.3     116.2    (------*-----)
                                   --------+---------+---------+--------
Pooled St Dev =    196.3                  150       300       450
```

Considering regional average utilization, Table 38 indicates that there are not significant differences. For regional annual operating hours, Table 39 shows the coastal regions are significantly higher in operating hours than either the mountain or the piedmont regions.

Table 38 Utilization by Region, Class 2002 Loader, 2008

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean    St Dev  ---------+---------+---------+-------
Coastal    66    0.3359    0.3034     (---------*--------)
Mountain   61    0.3103    0.3323   (--------*---------)
Piedmont   67    0.4563    0.4661                  (--------*--------)
                                   ---------+---------+---------+-------
Pooled St Dev =   0.3756                  0.30      0.40      0.50
```

Table 39 Annual Operating Hours by Region, 2008 Data

```
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean    St Dev  ------+---------+---------+---------+
Coastal    66     356.6     216.8                      (------*------)
Mountain   60     223.2     205.4  (-------*------)
Piedmont   67     283.1     187.1           (------*------)
                                   ------+---------+---------+---------+
Pooled St Dev =    203.3                210       280       350       420
```

2.6.1 Fleet Age – Front-end Loader

Table 40 shows data related to the age of the current fleet of front end loaders and presents a consistent picture of an aging fleet. Over the four years of the study data, the average age increased from 7.1 to 9.2 years, the median age increased from 6.2 to 9.2 years, the percent of the fleet less than ten years old decreased from 75% to 63%, and the number of units over ten years old increased from 49 to 80.

Table 40 Age Trends for Class 2002 Front End Loader

	2006	2007	2008	2009
Mean age (years)	7.1	8.1	9.1	9.2
Median age (years)	6.0	7.1	8.2	9.2
% fleet < =10 years	0.75	0.67	0.67	0.63
Count > 10 years	49	64	64	80

Figure 26 provides additional insight into the age issues highlighted in Table 40. About 19% of the fleet (42 units) is more than 15 years old as of 2009. As in the motor grader, significant future investment will be needed to modernize this fleet in the near future. Since the cost of one front end loader is equivalent to two dump trucks, this will have a significant impact in the replacement budget.

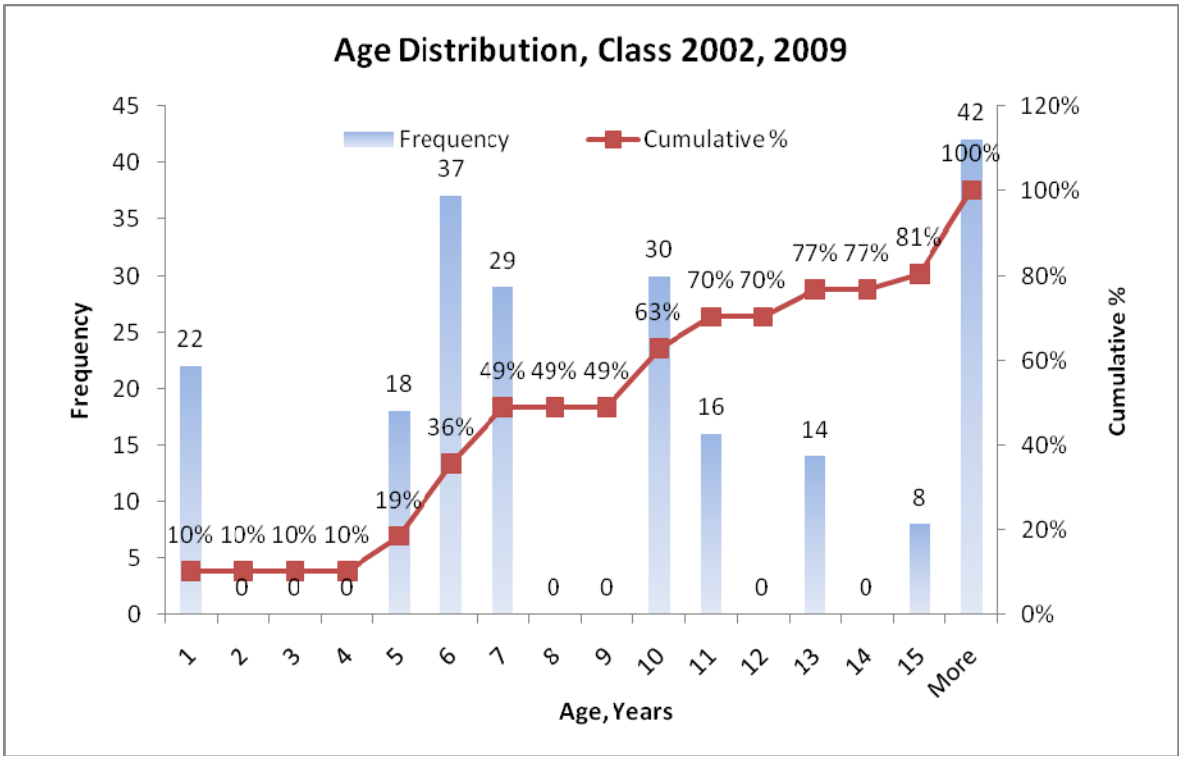

Figure 26 Age Distribution, Class 2002 Loader, 2009

2.6.2 Summary- Utilization of 2002 Front End Loader

In discussions with the project participants, about half of the 2002 units are stationed in storage yards to support loading materials onto trucks for projects. Inconsistency in charging these units appears to account for a large part of the low utilization. Due to distance and the logistics of frequent transport, it does not make sense to pool these units used for material handling. This yard assignment usage results in low utilization since the various project time they support with loading operations is typically not charged or recorded. It is important that these units are segmented as far as record keeping and utilization goals. One recommendation is that the yard based units could be placed on administrative status.

Per Table 24, 90 units showed utilization less than 20% while we estimate as many as 100 units may be on yard duty. Since it is not possible at this time to identify the units currently assigned to yard status and compare their current utilization levels relative to charging practices, we do not recommend significant reduction of the current 2002 fleet at this point. As noted above, we recommend segmenting the yard duty units and establishing the utilization targets proposed in Table 41 for class 2002 units not assigned to yard duty. This should result in an overall composite utilization above 60%.

Table 41 Proposed Class 2002 Fleet Composition

	Units	% Fleet	Average Util.	Total Hours	Average Hours
Utilization > 40% (day to day operation	67	64%	0.79	24,975	373
Utilization 20%-40% (spare, pool, or sporadic use)	37	36%	0.30	12,879	348
	104	Composite Util. =	0.61	37,854	

Although not recommended at this time, considering the issues mentioned above and possible overlap of yard units with units identified in Table 41, a reasonable long term fleet reduction target for this class is 20 units or 10% with a target fleet of about 190. It will be important to methodically examine the following opportunities related to increasing utilization, pooled units, and fleet size reduction:

- Negotiation of cost effective and flexible rental agreements.
- Development of pooled approaches for spare availability
- Exploration of rental units (with or without) operators to address tasks which are seasonal or require manpower which may not be consistently available.

2.7 Utilization Summary

This chapter examined the current status in utilization, fleet size, usage, and age. Discussions with project contacts in the divisions and with the project team indicated a range of potential directions for increasing utilization and they generally include:

- Identify the impact of the current operational mission on the work which can be consistently executed by NCDOT personnel based on the anticipated budget and manpower. It is clear that this point has resulted in decisions to retain equipment as a means of managing uncertainty about these key operational factors.
- Based on the results of the previous point, segment fleet size and utilization targets based on the consistently needed work (and the recommendations in this chapter) to enhance asset utilization. Equipment to support consistent, day to day operations should be modern, reliable, and highly utilized.
- Identify the work which is sporadic or inconsistent and explore alternative approaches for sourcing equipment to support these needs.
- Critically evaluate the need for spare or pooled equipment and how pools or rentals could be effectively developed to support this need.

- Based on sporadic and spare needs, identify the needed equipment levels and the target utilizations.

From an organizational perspective, these directions will also entail inter and intra division considerations:

- The importance of charging the vehicle for the entire time it is committed to use is critical. It is clear that this is causing understated utilization.
- The importance of considering divisional rental rates so the impact of local decisions is more readily apparent and beneficial.
- At the division level, consideration of ways to share vehicles between operating groups or department boundaries, such as maintenance and construction. For example, there are intervals between award or construction project phases which have detrimental impact on pickup truck utilization. Ways to share between operating groups would help this and other class utilization
- Development of an administrative fleet of trucks which could be centrally managed to help pool the ebb and flow of seasonal usage. Potential rental opportunities are also possible.
- Identification and sharing of best practices to address seasonal needs such as when summer students or part time inspectors are hired.

Summarized in Table 42, the proposals to reduce the fleet and increase utilization are conservative and recognize the realities of protecting public safety and maintaining the state's highway investment. We propose these goals be monitored and implemented using a team based project approach which will enhance the accuracy of the SAP data, share best practices, and search for innovative approaches to continually improve the use of equipment assets.

Table 42 Utilization Improvement Recommendation Summary

Class	2009 Fleet	2008 Utilization	Target Fleet Size	Target Utilization -Composite
0201	1366	63%	1160	74%
0205	1038	45%	744	58%
0206 (truck2)	379	37%	244	51%
0314	297	48%	222	57%
0900	434	39%	295	53%
2002	216	37%	216[3]	61%

Two final and important considerations should also be mentioned:

- The age of the fleet, in particular for off road units, is a significant concern, especially considering the replacement cost. Reduction of fleet size will positively impact this situation.
- It is important to manage equipment utilization based on its purpose, importance of need, and possible utilization. An example of this issue is the variety of items in class 0206 which should have specific goals identified.

[3] Potential long term reduction of approximately 20units after identification of yard material handling needs.

3 Market Value and Salvage Estimates

The market value, which can be realized if the particular item is disposed, is an important element in the decision model for the economic life of equipment. Within NCDOT, the concept of decline in value or usefulness has been commonly termed "depreciated life" or similar terms involving depreciation. To the wider public, "depreciation" represents the tax implications of decline in value of capital assets with use or passage of time and this depreciated value may or may not represent market value. We will use the terms market or salvage value in lieu of depreciation in this study. The optimal life model discussed in Chapter 5 integrates the findings of this section as a key element in the optimal life cycle model for the six classes. In summary, market or salvage value discussed in this chapter reflects the value NCDOT could realize if equipment is disposed, i.e. a market value for aged equipment.

In general, market value is a difficult data point to identify since it is based on condition at the time of sale. We have attempted to benchmark reasonable average values which reflect normal NCDOT wear and maintenance condition. It will be important, as the goals motivating this study are implemented, to continue to track actual market values over time and refine the data and methods discussed in this chapter. We examined several sources to identify the best approximations of market value.

- Historical data base of salvage sales by NCDOT.
- Market based construction equipment auction sites.
- Market valuation sites for commercial sales.

The following sections develop estimates of current purchase prices and how the market value of these assets decline over time with use for each of the six classes. They begin with examining the current purchase price and then review information on the history of disposal volume and age. They conclude with data summarizing the best estimates for the year over year decline in value.

3.1 Class 0201 Pickup Trucks

Table 43 presents the cost of class 0201 pickup trucks over the most recent years of the study period. No new pickup trucks were purchased in 2009 so the average cost of 2008 purchases, updated to $2009 ($19,239) will be employed in the optimal cost model as a starting point for the market value.

Table 43 Purchase Price History, Class 0201 Pickup

Year	2005	2006	2007	2008	2009
Average purchase price ($)	17618	16932	18968	19308	NA
CPI factor for $2009	1.10	1.06	1.03	0.996	1.00
Purchase price in $2009 ($)	19354	18018	19626	19239	NA

Table 44 contains the history of NCDOT disposal for class 0201 and indicates an aging disposal point. For example, in 2004, 267 class 0201 pickups were salvaged and the average age was 10.6 years. In 2009, 172 units were salvaged and the average age had increased to 11.3 years.

Figure 27 shows the decline in salvage value based on age. This data was developed by adjusting the value realized at the time of salvage to $2009 using the appropriate consumer price index[4] and plotting the result by the age at the time of disposal.

Table 44 History of NCDOT Class 0201 Sales, Number and Average Age

Year	Number Sold	Average Age
1994	5	13.2
1995	190	9.7
1996	109	9.3
1997	154	8.9
1998	238	9.0
1999	198	9.6
2000	97	9.9
2001	169	10.1
2002	182	10.6
2003	147	10.1
2004	267	10.6
2005	115	10.5
2006	128	10.7
2007	231	10.7
2008	222	11.4
2009	172	11.3

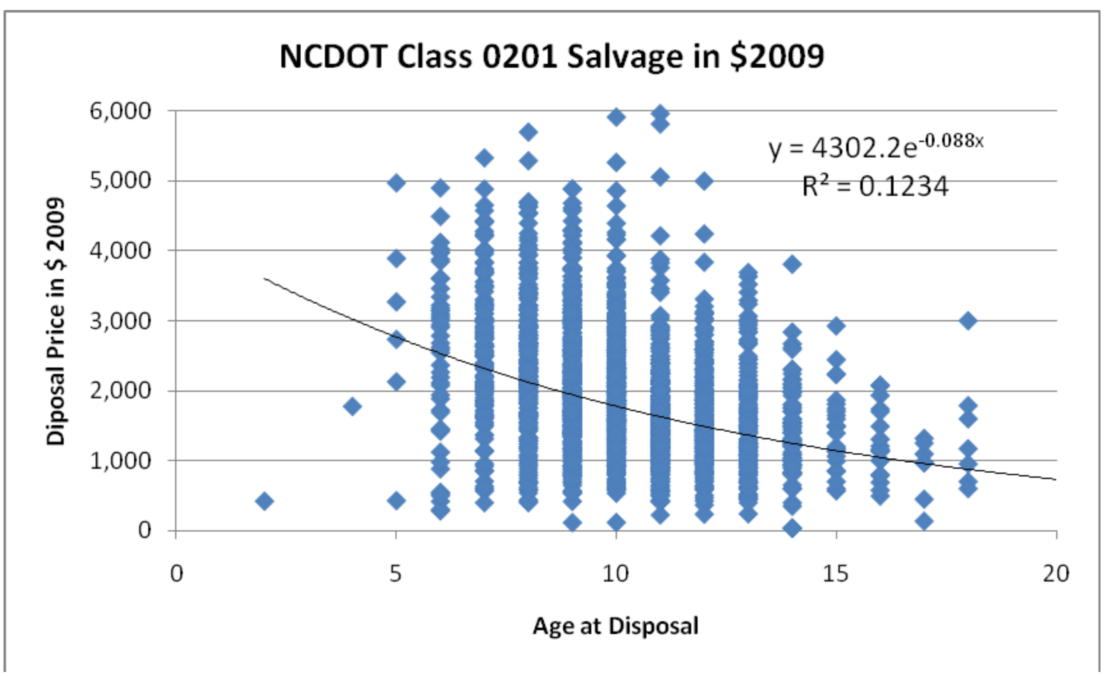

Figure 27 NCDOT Salvage Value by Age, Class 0201, 2009 $

[4] Consumer price index table values obtained from ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt

Figure 27 illustrates the challenge in using past data to forecast future trends. The data is noisy and covers a limited age interval, representing trucks disposed from roughly the 6^{th} to the 15^{th} year of operation. In general, records indicate trucks disposed in this interval often had significant problems (engine, transmission, etc.) which negatively impacted the market value realized. However this data does represent a base line trend for decline in value of class 0201 equipment based on the historical experience of NCDOT in salvage sales.

Figure 27 contains an exponential equation fit for the decline in salvage value over time. This equation was identified based on minimizing the squared error terms where error is the forecast value from the equation minus the actual sale value. We selected exponential equations as the best fit to represent the year over year compounded decline in value of equipment from both a statistical and common sense perspective. Chapter 5 discusses this decision in more detail.

One of the advantages of an exponential function is the ability to identify a year by year percentage decline (or increase). For example, equation 2 is the basic conversion equation to an annual equivalent year by year decline in value for the NCDOT salvage exponential function in Figure 27.

$$i = 1 - e^{-0.088} = 0.084 = 8.4\% \qquad \textbf{Equation 2}$$

As a contrast to the 8.4% annual value decline estimated from NCDOT salvage data, Figure 28 presents market based salvage values from the NADA web site[5]and plots two data sets for the Ford F-150[6] pickup truck: average trade in and clean retail. By applying an approach such as describe for equation 2 to the exponential equations in Figure 28, clean retail represents a 13% annual decline and average trade in represents a 17.4% decline year over year. These rates of decline are significantly higher and the values expected to be realized are significantly more on an age to age comparison basis than the current NCDOT data shows.

There are two related reasons for these differences. First, NADA data represents a functional vehicle with remaining service life potential to the buyer. As previously noted, NCDOT salvage value typically reflects a vehicle with reduced “as-is” service potential to the buyer. Second, NADA represents a continuous decline from time of purchase where NCDOT only reflects equipment six or more years old.

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[5] NADA- National Automotive Dealers Association, www.**NADA**AppraisalGuides.com

[6] A high percentage of recent purchases for class 0201 have been Ford F-150.

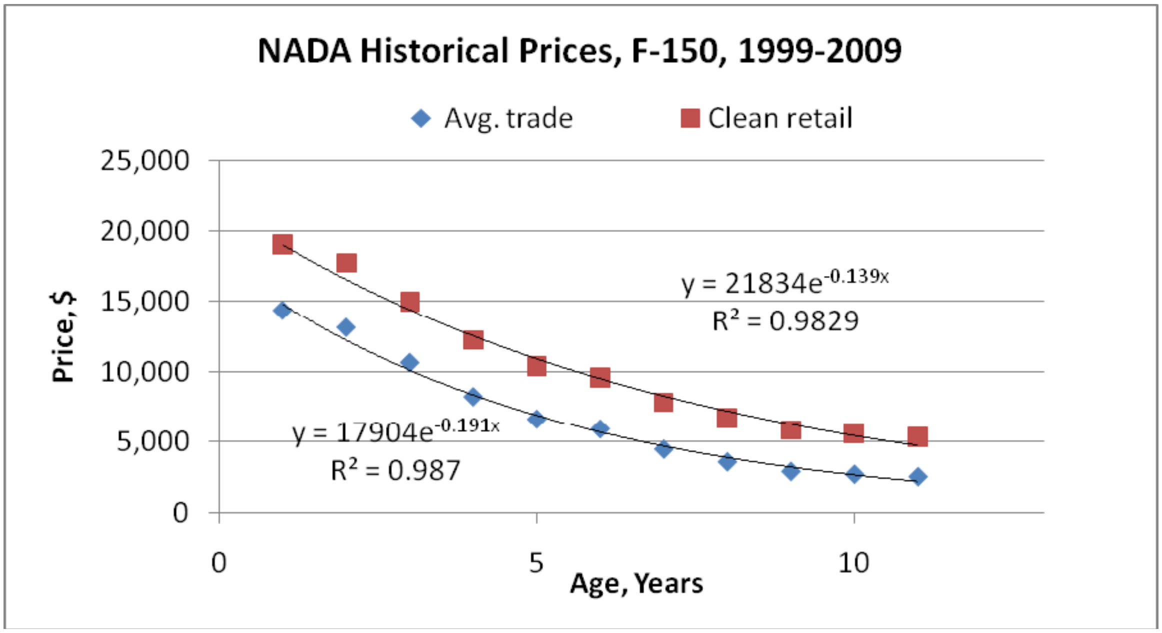

Figure 28 NADA Historical Market Price Decline, F-150 Pickup Truck

In summary, an important data point for the optimal disposal life is the annual rate of decline in value and we have identified values between a low of 8.4% and as high as 17.4% for class 0201. As will be discussed at the end of this chapter, we generally selected target decline rates above the current NCDOT values but below the market rate values. This selection was based on the view that this is more reflective of the sale price NCDOT may realize in the future with a new approach to equipment life cycle costs. These values and their impact on the optimal life will be explored in the chapter 5 discussion of optimal life.

3.2 Class 0205 Single Axle Dump Truck

Table 45 presents the purchase price history of class 0205 dump trucks over the years of the study period. Since trucks were purchased and placed in service in 2009, we plan to use this price point ($51,583) as the representative new cost.

Table 45 Purchase Price History, Class 0205 Single Axle Dump Truck

Year	2005	2006	2007	2008	2009
Average purchase price	41,642	0	44,243	49,911	51,853
CPI factor for $2009	1.10	1.06	1.03	0.996	1.0
Purchase price in $2009	45,744	0	45,778	49,733	

Table 46 presents the history of class 0205 disposals and indicates an aging disposal point. For example, in 2004, 114 class 0205 trucks were salvaged and the average age was 11.8 years. In 2009, 66 units were salvaged and the average age had increased to 14.1 years.

Figure 29 shows the decline in salvage value based on age. This data was developed by adjusting the value realized at the time of salvage to $2009 using the appropriate consumer price index and plotting the result by the age at the time of disposal. Using an approach parallel to that discussed in relation to equation 2, this data represents a 4.5% decline in value from the 9th to the 18th year of age.

Table 46 NCDOT Salvage History, Class 0205 Dump Truck

Year	Number Sold	Average Age
1994	3	8
1995	69	11.1
1996	162	10.8
1997	39	12.1
1998	99	11.2
1999	32	11.6
2000	42	12.3
2001	152	11.6
2002	84	12.8
2003	48	12.5
2004	114	11.8
2005	103	12.4
2006	49	14.0
2007	89	13.5
2008	64	13.4
2009	66	14.1

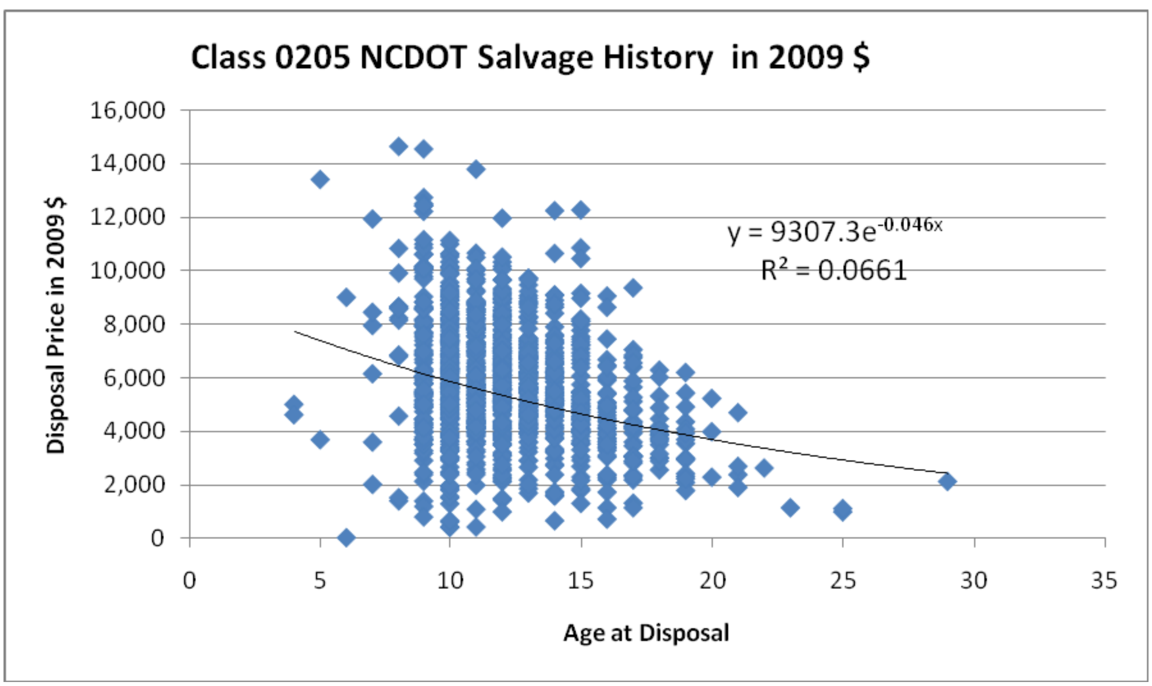

Figure 29 NCDOT Salvage Value by Age, Class 0205, 2009$

Figure 30 provides a comparative perspective on market value of class 0205 vehicles. This data was developed from a composite of historical sales provided by two construction equipment auction sites: Ritchie Brothers and Machinery Trader.[7] Auction sales information for the previous three years is available from these sites. Figure 30 shows the results of searching these sites and matching the results to parallel as consistently and closely as possible with the NCDOT class 0205 models. Plotting this data and identifying an exponential best fit equation (shown in Figure 30) indicates the year over year decline in value for class 0205 is 12.8%, based on these commercial websites.

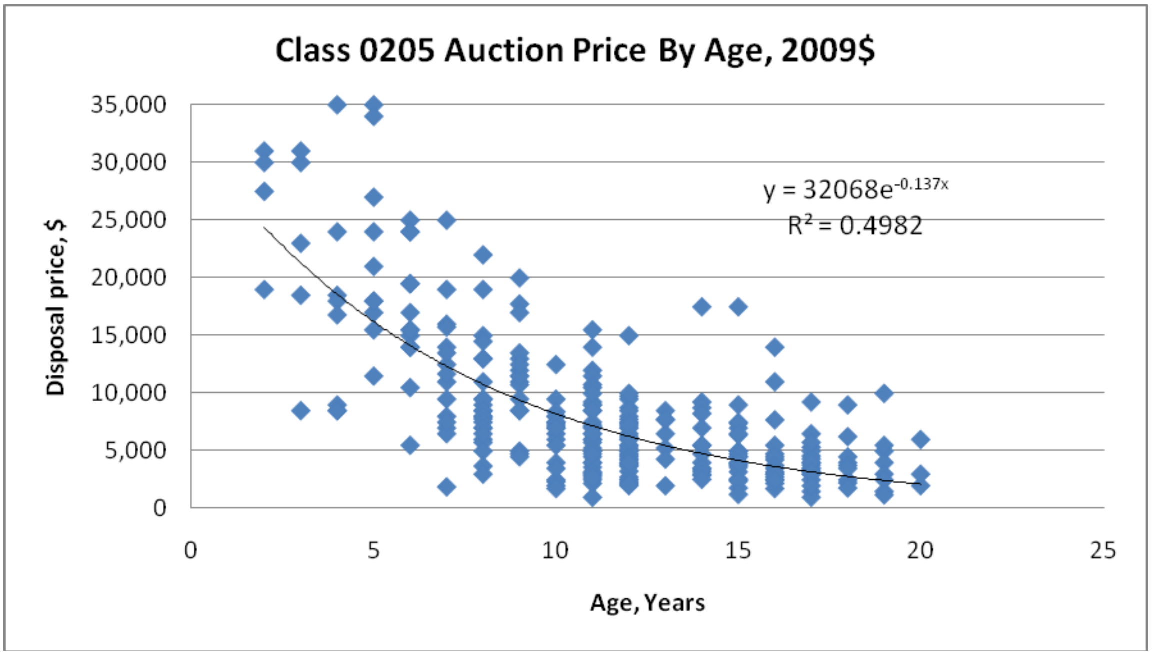

Figure 30 Commercial Web Site Auction Values by Age, Class 0205, $2009

3.3 Class 0206 Flat Bed and Miscellaneous Truck

Class 0206 is comprised of a wide range of variations as discussed in the previous chapter. This section examines only the flat bed "Truck 2" variety since it is the largest and most comparable to large data sets. Table 47 presents the purchase price history of class 0206 flat beds over the years of the study period.

Table 47 Purchase Price History, Class 0206 Flat Bed Truck

Year	2006	2007	2008	2009
Average purchase price $	NA	43,735	49,850	52,130
CPI factor for $2009	1.06	1.03	0.996	1
Purchase price in $2009	NA	45,047	49,651	52,130

Table 48 presents the history of class 0206 disposals and indicates an aging disposal point. For example, in 2004, 63 class 0206 trucks were salvaged and the average age was 14.4 years. In 2009, 40 units were salvaged and the average age had increased to 16.2 years.

[7] These web sites are www.rbauction.com and www.machinerytrader.com

Figure 31 shows the decline in salvage value based on age for NCDOT disposals. This data was developed by adjusting the value realized at the time of salvage to $2009 using the appropriate consumer price index and plotting the result by the age at the time of disposal. Using an approach parallel to that discussed in relation to equation 2, this data represents an 8.7% decline in value from roughly the 10th to the 20th year of age.

Table 48 NCDOT Salvage History, Class 0206 Flat Bed Truck

Year	Number Sold	Average Age
1995	66	12.1
1996	59	13.2
1997	16	12.9
1998	37	14.0
1999	32	15.5
2000	27	14.5
2001	51	12.9
2002	40	15.8
2003	37	14.0
2004	63	14.4
2005	49	13.9
2006	29	14.7
2007	26	14.8
2008	44	15.7
2009	40	16.2

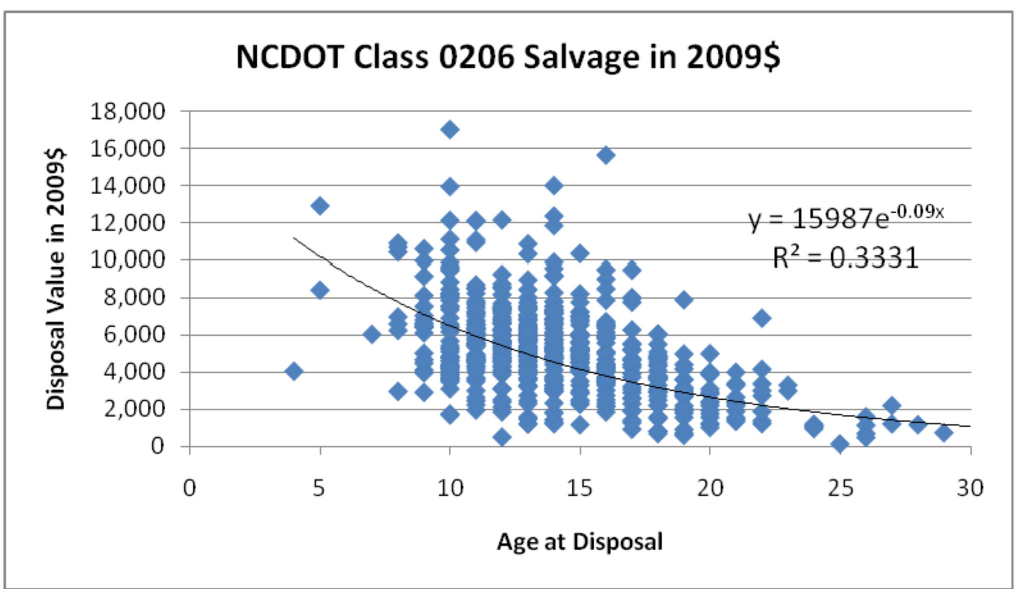

Figure 31 NCDOT Salvage Value by Age, Class 0206, $2009

Figure 32 provides the commercial web site results for the decline in market value of class 0206 vehicles. This data was developed from a composite of historical sales provided by the two construction equipment auction sites previously noted. These values were searched and matched to parallel as consistently and closely as possible with NCDOT class 0206 models. Plotting the data and identifying an exponential best fit equation (shown in Figure 29) indicates the year over year decline in value for class 0206 is 10.5%.

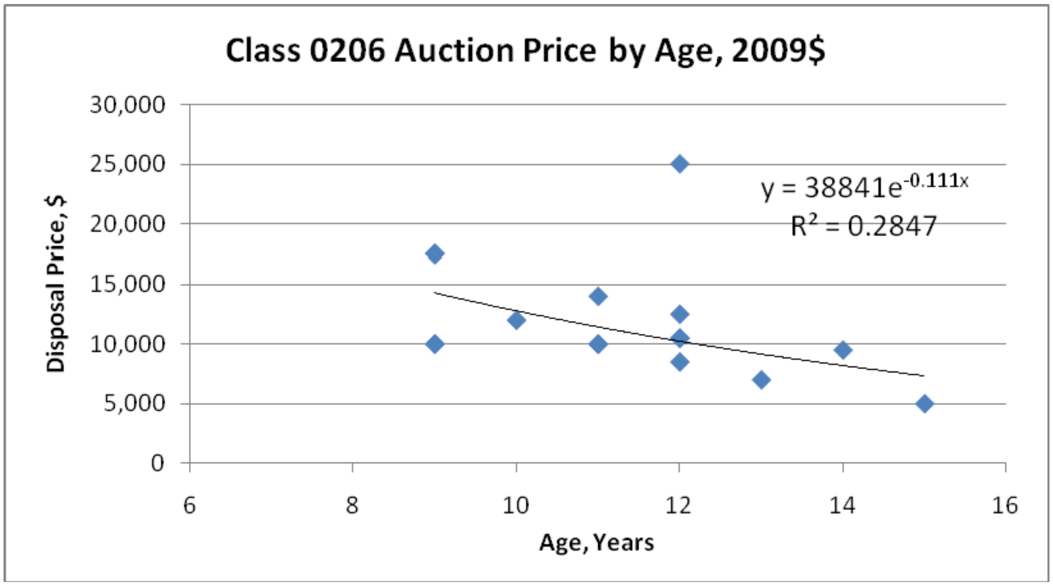

Figure 32 Auction Values by Age for Class 0206, 2009$

3.4 Class 0314 Loader-Backhoe

As noted in Table 49, the last purchase of class 0314 loader-backhoe units was 2008 and the average cost was $71,574. In $2009

Table 49 Purchase Price History, Class 0314 Loader-Backhoe

Year	2006	2007	2008	2009
Average purchase price	68,226	69,115	71,861	NA
CPI factor for $2009	1.06	1.03	0.996	1
Purchase price in $2009	72,319	71,188	71,574	NA

Table 50 presents the history of class 0314 disposals and indicates an aging disposal point. For example, in 2007, 10 class 0314 units were salvaged and the average age was 9.7 years. In 2009, 16 units were salvaged and the average age had increased to 11.8 years. Figure 33 shows the decline in salvage value based on age per NCDOT salvage data. Using an approach parallel to that discussed in relation to equation 2, this data represents a 3.4% decline in value with data points concentrated in the 10^{th} to the 15^{th} year of age.

Figure 34 presents the commercial auction web site data for the decline in market value of class 0314 units. The exponential best fit equation (shown in Figure 34) indicates the year over year decline in value for class 0314 in a commercial auction context is 6.2%.

Table 50 NCDOT Salvage History, Class 0314 Loader-Backhoe

Year	Number Sold	Average Age
2002	1	14
2004	4	16.5
2005	1	9
2006	1	10
2007	10	9.7
2008	18	10.1
2009	16	11.8

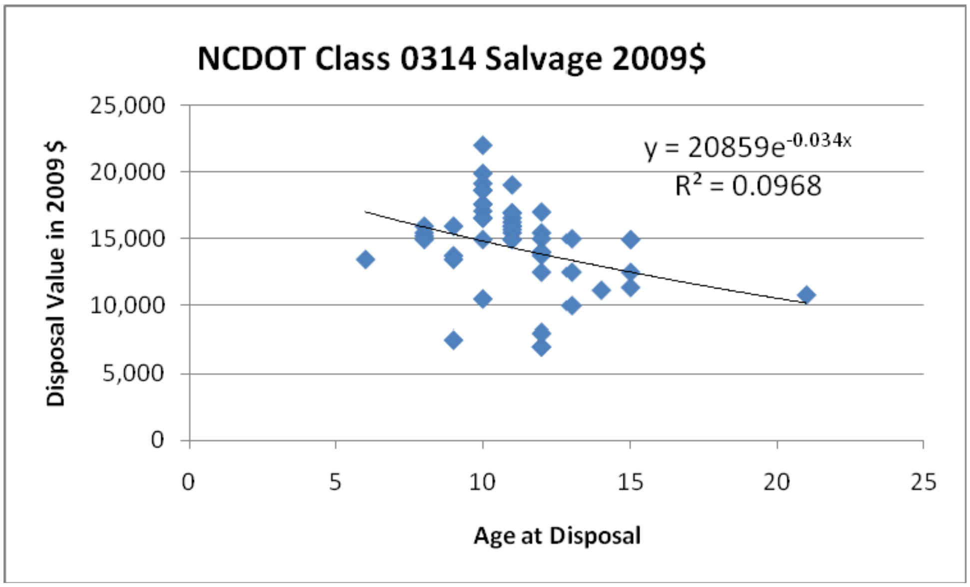

Figure 33 NCDOT Salvage Value by Age, Class 0314, 2009$

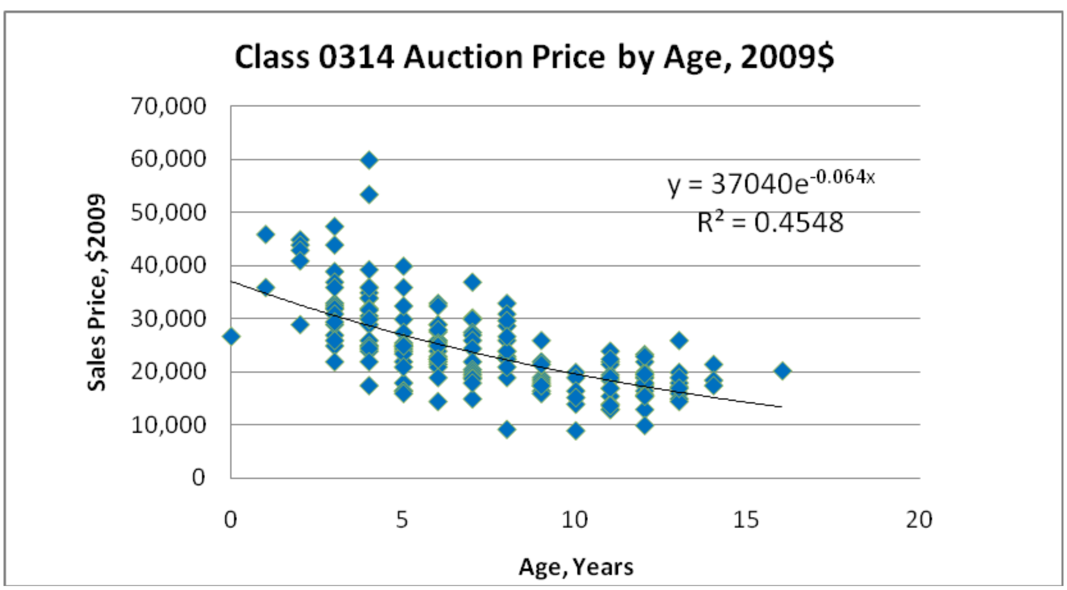

Figure 34 Auction Values by Age for Class 0314, 2009$

3.5 Class 0900 Motor Grader

Purchases of class 0900 units have been inconsistent over the period of the study. The cost of the most recent purchase in 2008 was $154,030 in 2009$ per Table 51.

Table 51 Purchase Price History, Class 0900 Grader

Year	2006	2007	2008	2009
Average purchase price	NA	146,004	154,649	NA
CPI factor for $2009	1.06	1.03	0.996	1
Purchase price in $2009	NA	150,384	154,030	NA

Table 52 presents the history of class 0900 disposals and indicates an aging disposal point. For example, in 2004, 54 class 0900 units were salvaged and the average age was 14.1 years. In 2009, 37 units were salvaged and the average age had increased to 15.6 years.

Figure 35 shows the decline in value based on age for NCDOT salvage. Using an approach parallel to that discussed for equation 2, this data represents a 2.5% decline in value with data points concentrated in the 11th to the 19th year of age.

Table 52 NCDOT Salvage History, Class 0900 Grader

Year	Number Sold	Average Age
1994	1	14.0
1995	35	14.3
1996	20	16.1
1997	24	14.4
1998	61	14.5
1999	53	14.8
2000	10	17.3
2001	40	12.8
2002	26	14.4
2003	42	13.4
2004	54	14.1
2005	27	14.4
2006	22	14.8
2007	33	15.1
2008	25	16.1
2009	37	15.6

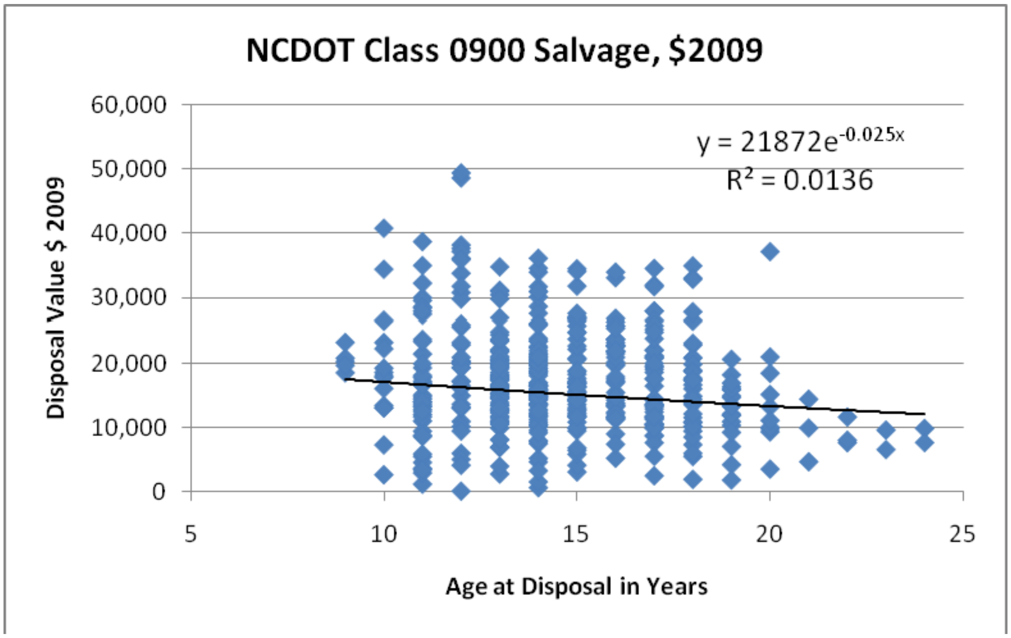

Figure 35 NCDOT Salvage Value by Age, Class 0900, $2009

Figure 36 presents the commercial auction web site data on the decline in market value of class 0900 units. The exponential best fit equation (shown in Figure 36) indicates the year over year decline in value for class 0314 in a commercial auction context is 9.1%.

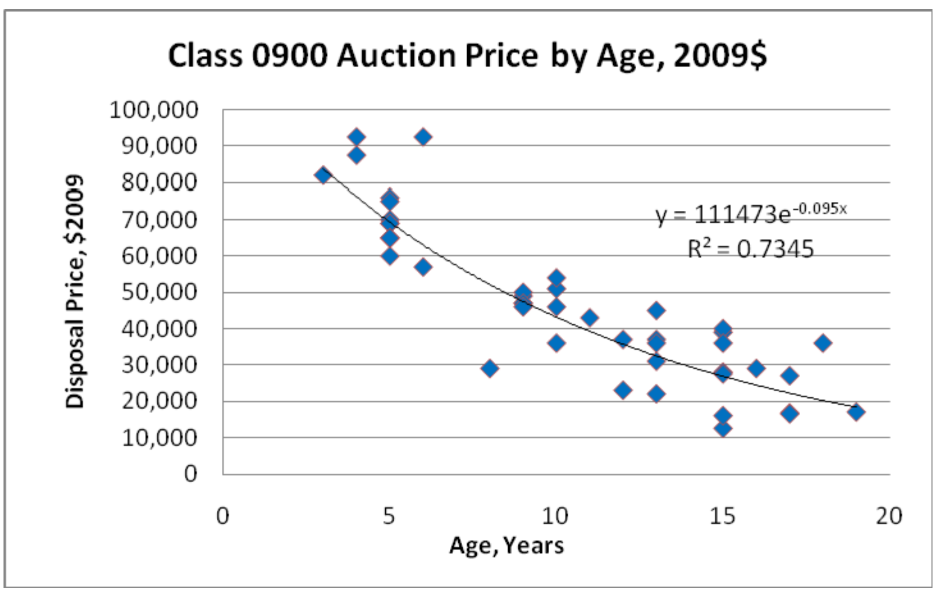

Figure 36 Auction Values by Age for Class 0900, 2009$

3.6 Class 2002 Front End Loader

During the period of the study, 16 units were purchased in 2005 and placed in service in 2006 and 22 were purchased in 2008. The most recent inflation adjusted purchase price shown in Table 53 was $107,364.

Table 53 Purchase Price History, Class 2002 Front End Loader

Year	2005	2006	2007	2008	2009
Average purchase price	84,387	NA	NA	107,795	NA
CPI factor for $2009	1.1	1.06	1.03	0.996	1
Purchase price in $2009	92,825	NA	NA	107,364	NA

Table 54 presents the history of class 2002 disposals and indicates an aging disposal trend. For example, in 2004, 23 class 0900 units were salvaged and the average age was 15.0 years. In 2009, 17 units were salvaged and the average age had increased to 17.4 years.

Figure 37 shows the decline in salvage value based on age using historical NCDOT information. Using an approach parallel to that discussed for equation 2, this data represents a 5.5% decline in value with data points concentrated roughly the 10^{th} to the 20^{th} year of age.

Figure 38 provides the commercial auction website data for decline in market value of class 2002 units. The exponential best fit equation (from Figure 38) indicates the year over year decline in value for class 2002 in a commercial auction context is 7.9%.

Table 54 NCDOT Salvage History, Class 2002 Front End Loader

Year	Number Sold	Average Age
1994	1	11.0
1995	7	14.7
1996	4	18.5
1997	16	16.1
1998	3	16.0
1999	6	17.0
2000	5	20.8
2001	12	15.3
2002	9	18.1
2003	9	15.3
2004	23	15.0
2005	14	14.8
2006	15	16.4
2007	11	16.5
2008	4	21.5
2009	17	17.4

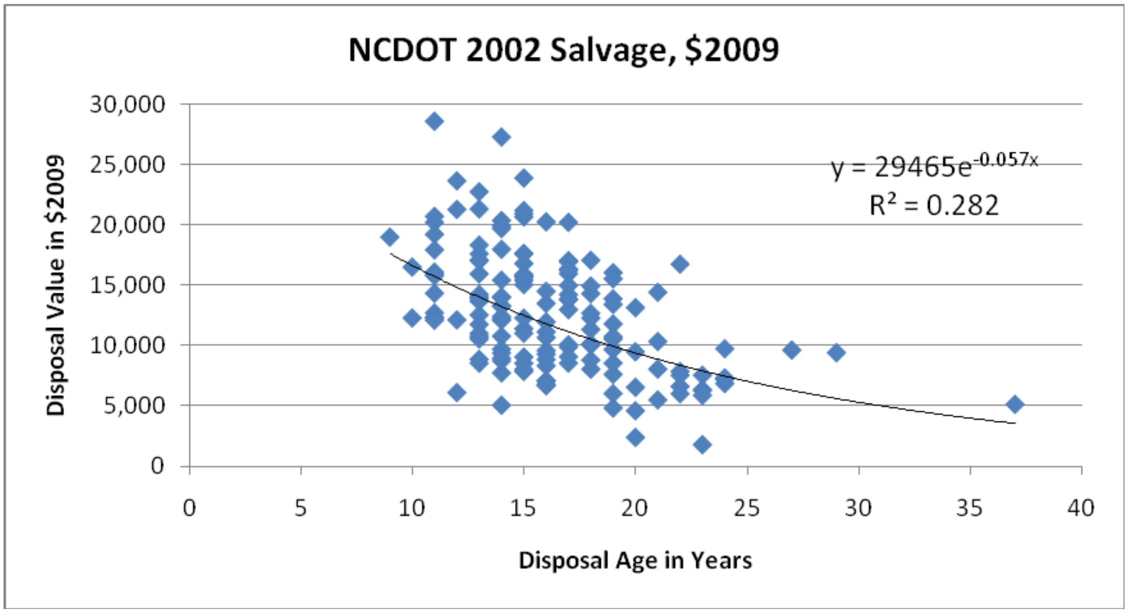

Figure 37 NCDOT Salvage Value by Age, Class 2002, 2009$

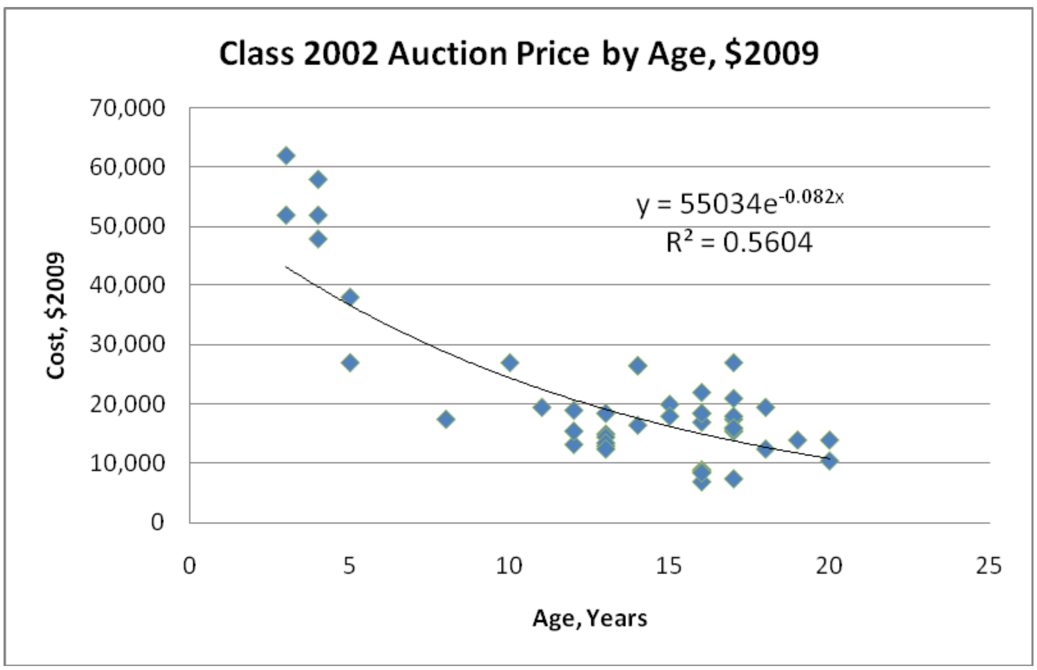

Figure 38 Auction Values by Age for Class 2002, 2009$

3.7 Summary- Salvage Values

This section examined the trends related to decline in value of the six classes in the study. Exponential decay equations were fitted to the best information available from the NCDOT historical salvage database and two commercial auction services that maintain several years of historical information. The exponent in these equations was then converted to an annual percentage decline in value and those results are shown in Table 55.

The decline rates in Table 55 represent a bracket for the actual rate of decline NCDOT equipment will experience using a consistent and periodic equipment replacement approach, based on an optimal economic life. On the low end, the NCDOT rate represents very used, old equipment between ten and twenty years old, with questionable remaining life from the purchaser's perspective. On the high end, the market price column represents the value decline of used equipment with a more reliable remaining service life to the purchaser, generally representing newer equipment with significant remaining life. We selected decline rates (far right column) which were realistic starting points for the economic life model based on the data in this chapter. It will be important over time to continue to refine this information as disposals occur and we continue to gather annual information on equipment disposal values. These purchase price values and decline rates will be integrated into the optimal life model in Chapter 5.

Table 55 Summary of Price and Value Decline Rates

Class	Estimated Purchase Price ($)	Annual Decline Rate- NCDOT Salvage History	Annual Decline Rate- Market Price or Auction History	Decline Rate for Optimal Life Model
0201 Pickup	19, 239	8.4%	13-17.4%	10%
0205 Dump Truck	51,853	4.5%	12.8%	10%
0206 Flat Bed	52,130	8.7%	10.5%	9%
0314 Loader- Backhoe	71,574	3.4%	6.2%	8%
0900 Grader	154,030	2.5%	9.1%	8%
2002 Loader	107,364	5.5%	7.9%	8%

4 Operating Cost and Use as a Function of Equipment Age

This chapter examines operating cost and use patterns for the six classes and how these parameters vary with equipment age. These are two critical components of the optimal life models examined in Chapter 5. The following paragraphs provide introductory information on how the calculations were performed.

The first component examined is annual operating costs and this was evaluated on a cost per-mile (classes 0201, 0205, 0206) or cost per-hour (classes 0314, 0900, 2002) basis, using data from the SAP system for the 2006-2009 period. Operating cost was calculated as the sum of the following cost items: PM labor, repair labor, PM parts, repair parts, parts, fuel, oil, and tires. This sum was divided by the number of miles (for on road) or operating hours (for off road) to develop an annual operating cost for each asset. Equipment age was calculated in years by subtracting the start-up date for each piece of equipment from the end date of the year being evaluated and dividing by 365.25 days/year (Excel stores dates as the number of days since January 1, 1900). When integers were needed for plots, the age was rounded up to be consistent with the approach used by Excel in histograms.

As a starting point for analysis of operating cost, for each year of study data, the annual operating cost per mile or cost per hour was plotted versus the age of the item and best fit descriptive equations were investigated. Figure 39 is an example of these plots and contains the class 0201 pickup truck cost per mile for 2009, showing both a linear and an exponential equation along with R^2, the coefficient of determination.[8] In general, exponential equations provided a consistently better fit to model the operating cost data based on two factors.

- First, the coefficients of determination were higher for the exponential equations compared to the linear equations.
- Second the exponential equations were more accurate in predicting the total annual operating cost. For example, the exponential equation shown in Figure 36 estimated the total annual cost for class 0201 trucks in 2008 with only a 6.6% error compared to over 27% for the linear equation.

The following narrative explains the relationship of the exponential equations and the annual estimated percentage change in cost. This information also applies to the exponential equations discussed in Chapter 3, representing market value decline, with the exception of a sign change.

[8] R^2 is commonly called the coefficient of determination and is the proportion of variability in a data set that is accounted for by the fitted equation. It provides a general measure of how well future outcomes are likely to be predicted by the model.

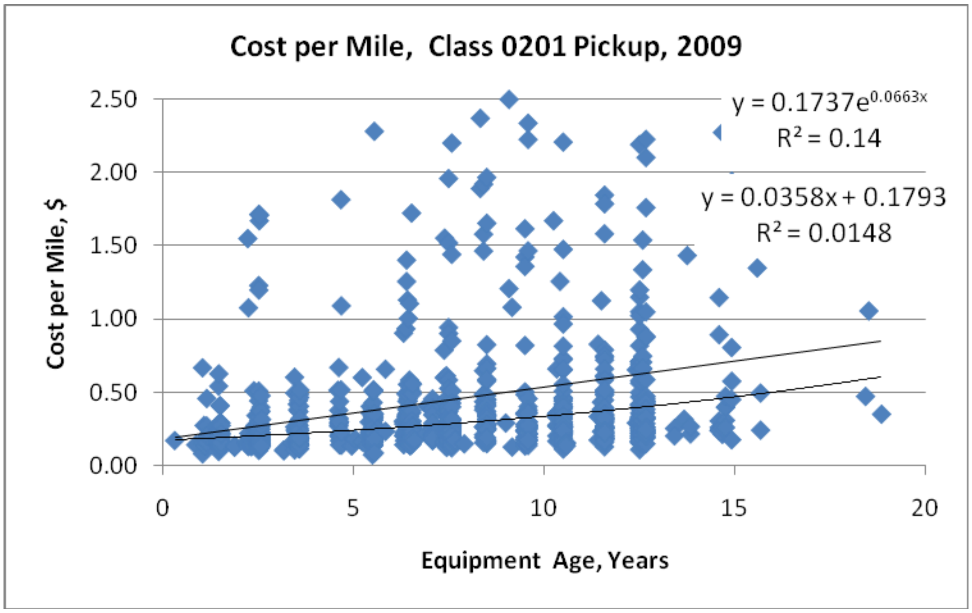

Figure 39 Cost per Mile, Class 0201, 2009

The rate of cost increase (or salvage value decrease as discussed in Chapter 3) can be obtained by manipulation of the exponential fit equation. An equation that predicts the cost by a percentage increase per year has the form:

$$F = P(1 + i)^n$$ **Equation 3**

Where F = the future cost per mile or hour when the piece of equipment is n years old, based on a present cost per mile or hour of P when the equipment is new and an annual percentage cost increase of i. Since the exponential curve fit uses a base e, the equation has the form:

$$y = Ae^{Bx}$$ **Equation 4**

Equation 4 can be rearranged as:

$$y = A(e^B)^x$$ **Equation 5**

Equations 3 and 5 are identical if y = F, A = P, x = n, and

$$e^B = (1 + i)$$ **Equation 6**

Therefore, the annual rate of cost increase is:

$$i = e^B - 1$$ **Equation 7**

For the plot shown above, the annual cost increase is:

$$i = e^{0.0663} - 1 = 0.685 \text{ or } 6.85\%$$ **Equation 8**

Using this approach we examined the operating cost trends for each of the years in the study data for each equipment class. By analyzing the increase in operating cost for each year individually on a percentage change basis, we are able to simplify cost variation issues related to inflation for the various cost components such as gasoline or tires.

In analysis of the 24 yearly operating cost plots (six classes and four years), we had two alternatives in general to identify the approach for the optimal cost model: select a composite or average value for each asset or select a representative year. Since each year represented a different distribution of ages, it was inappropriate to attempt to average percentages which represented different aged assets. Consequently we elected to select the most representative year. Although 2009 was not a typical operational year, the operating cost per mile or hour in that year should not have been impacted by the budget curtailment issues. In addition, 2009 reflects the most recent age distribution of the equipment and this is the most important model factor. As a result of these considerations, we elected to use 2009 results for the cost per mile or cost per hour calculations in Chapter 5. Those plots are presented and discussed in the following sections.

The second critical optimal life component discussed in this chapter is the pattern of usage variation with age over the life of the asset. The best performance of the optimal life model results if equipment is used consistently throughout its life. This is not now the case and may take several years to accomplish this goal. Consequently, we identify the current usage –age pattern so it can be integrated into the optimal life model. As time progresses and the collaborative efforts to improve fleet utilization produce results, we anticipate these usage patterns will be more consistent over asset life. As we discussed in Chapter 3, 2008 represents the most recent year of typical operation with fleet sizes near current levels. Consequently, we selected this year as the best example of current usage patterns. Once again, this will need to be tracked as utilization improves and fleet size changes over the next several years.

As a final introductory note, we raise the issue of "outliers." In relation to this chapter and Chapter 3, we examined different approaches to filter out data which may not be representative. In discussions with the project management team, it became clear that any attempt at filtering the raw data ran the risk of eliminating the variation which is an element of the current equipment use and cost practice. Consequently, with the exception of data which is clearly in error, we did not filter data points.

4.1 Class 0201 Pickup- Cost and Use Trends

Table 56 examines the average cost per mile and shows these values for the four years of data, adjusted to $2009. These values are presented as one comparative benchmark. We note that the average is not a good measure, in the case of many of these classes and years, for where this scattered data is "centered." This is primarily a result of the fact that the data is asymmetrical and there are many more data points which are skewed high than are skewed low. Per the information in Table 6, which showed the increase in fleet age for class 0201, this increasing cost per mile trend is not surprising.

Table 56 Average Cost per Mile, Class 0201, \$2009

	2006	2007	2008	2009
Average Cost per Mile	\$0.34	\$0.42	\$0.52	\$0.43

Figure 39 above plotted the cost per mile data by age for class 0201 in 2009 and projects a 6.85% annual increase in the cost per mile, using equation 8. The annual mileage of pickup trucks declines as they age and Figure 40 presents the plot of all the data points based on 2008 usage. For representing the decline in annual miles or hours with age, we elected to employ a linear equation in Figure 40 for a key practical reason. Choice of an exponential decline would have stipulated that there is a realistic, residual "usage" level which would reflect advanced age (as in Figure 37 or 38). Although this makes sense for a residual salvage value, this does not make sense for annual asset usage. For 2008, this linear equation shows a decline in use of 529 miles for each additional year of age from the first year peak of 14,710.

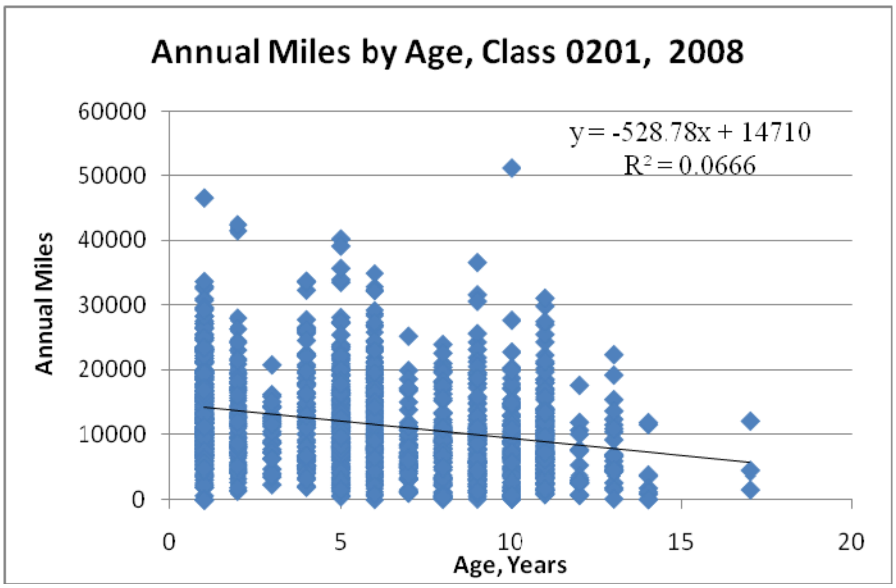

Figure 40 Annual Miles by Age, Class 0201, 2008

4.2 Class 0205 –Single Axle dump trucks

Table 57 presents the average cost per mile for class 0205 over the period of the study. In general, operating cost has been increasing in parallel with the increase in the age of the 0205 fleet (Table 12).

Table 57 Average Cost per Mile, Class 0205, \$2009

	2006	2007	2008	2009
Average Cost per Mile	1.94	1.43	1.49	1.66

Figure 41 plots the cost per mile of class 0205 for 2009 and indicates a 7.37% annual increase in cost per mile, beginning at \$0.61 per mile initially. Figure 42 shows the trend in miles per year based on age for 2008 and indicates an annual mileage decline of 540 miles per year of age from the base of 12,650 annual miles.

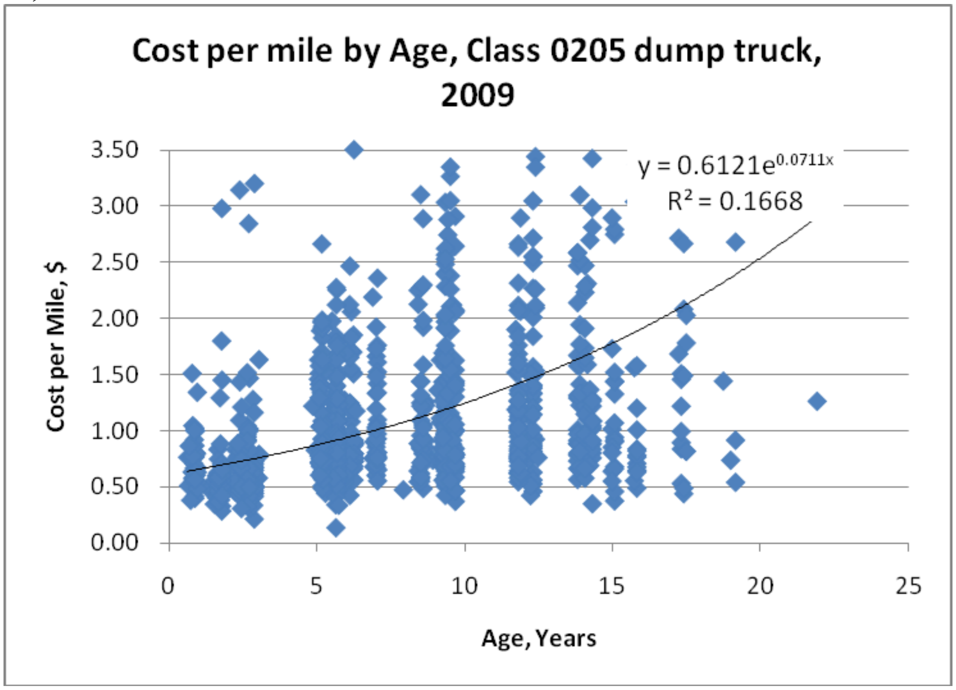

Figure 41 Cost per Mile, Class 0205, 2009

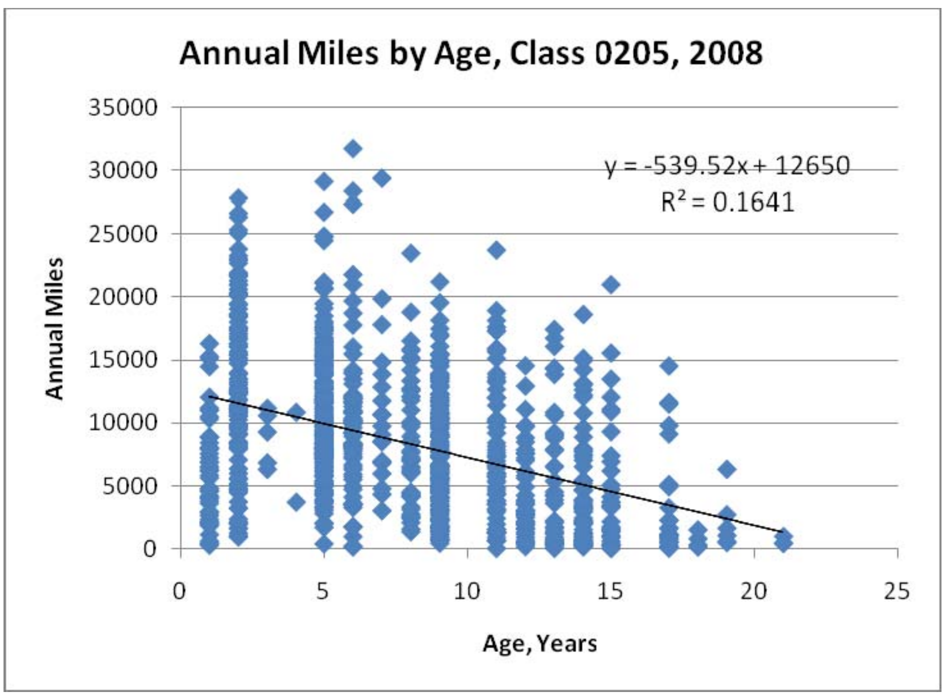

Figure 42 Annual Miles by Age, Class 0205, 2008

4.3 Class 0206 –Flat Bed Trucks

This section focuses on the largest component in class 0206, the flat bed trucks. Table 58 tracks the average cost per mile for the class 0206 and shows an increasing trend over the four years, in parallel with the increasing age of this class.

Table 58 Average Cost per Mile, Class 0206, $2009

	2006	2007	2008	2009
Average Cost per Mile	$2.57	$1.19	$2.02	$3.10

Figure 43 plots the cost per mile data and plots the trend of that value with age of the asset for 2009. Class 0206 truck2 units increase 5.76% per year from the base of $0.56 per mile, representing both a smaller base and smaller increase rate than for the similar class 0205 dump truck (starting at $0.61 and increasing over 7% per years. Figure 44 shows the annual miles trend declines 227 miles per year from a peak of 7,944. This compares with starting point over 12,000 miles and an annual decline of 539 for class 0205.

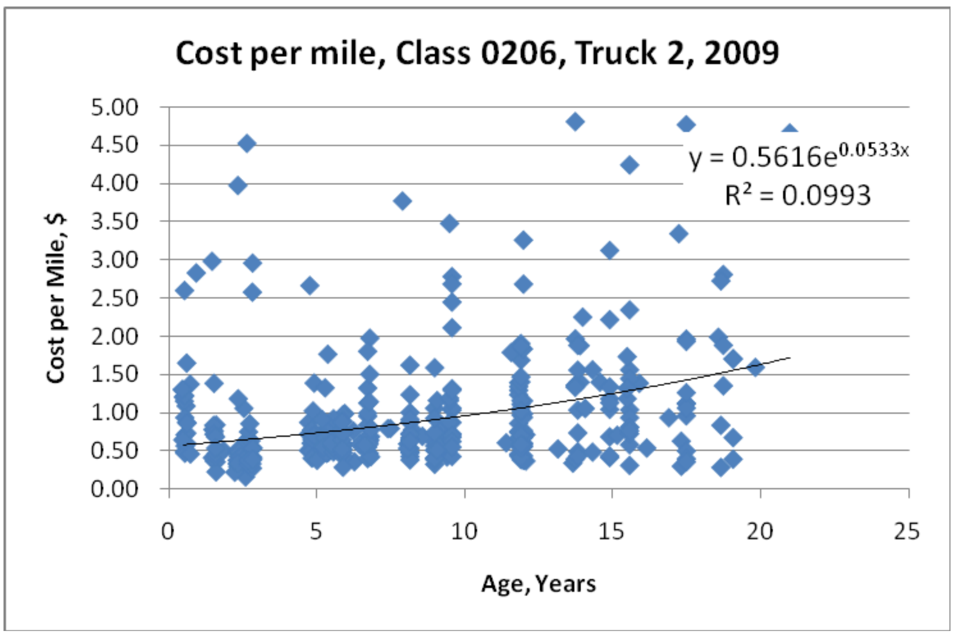

Figure 43 Cost per Mile, Class 0201, 2009

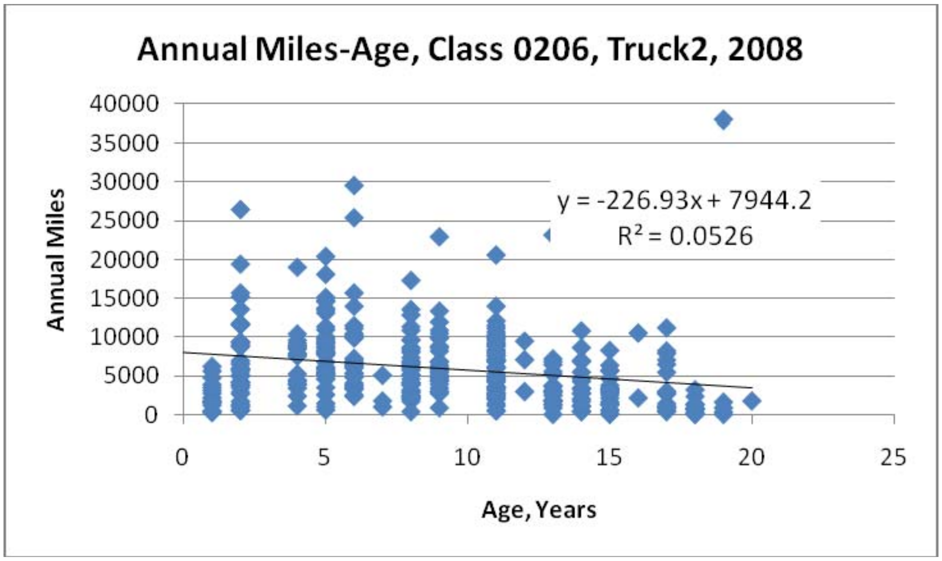

Figure 44 Annual Miles by Age, Class 0206, 2008

4.4 Class 314 –Loader / Backhoe

Table 59 presents the average operating cost per hour for the class 0314 loader – backhoe and shows an increasing trend, consistent with the increase in age of this fleet shown in Table 23.

Table 59 Average Cost per Mile, Class 0314, $2009

	2006	2007	2008	2009
Cost per hour	$21.17	$25.63	$23.81	$32.74

Figure 45 plots the cost per hour data by age for 2009 and indicates an estimated annual increase rate of 8.1% per year from a starting point of $12.72 per hour. Figure 46 plots the decline in usage of the fleet as it ages and estimates that operating hours decline by 24 per year from the base of 541.

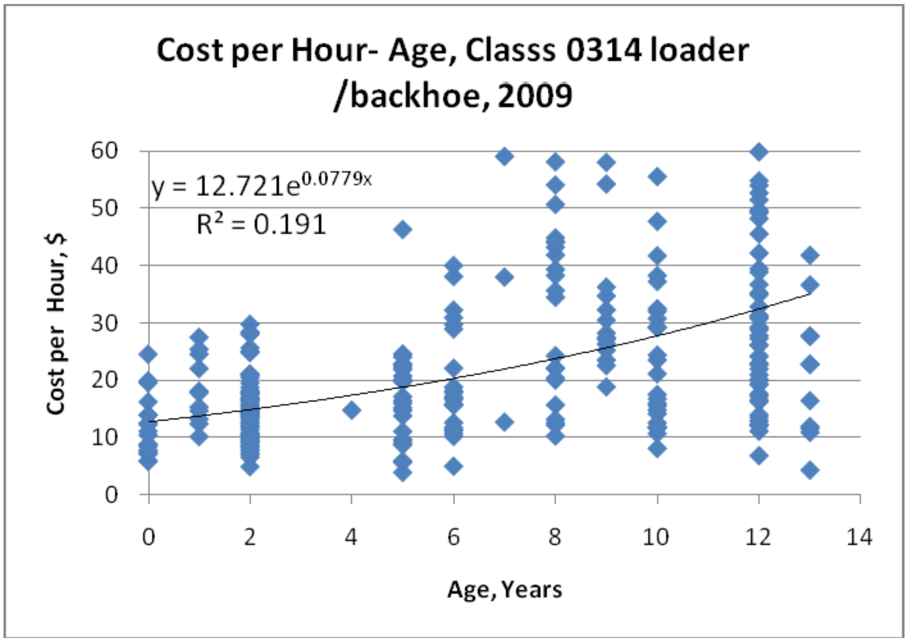

Figure 45 Cost per Hour, Class 0314, 2009

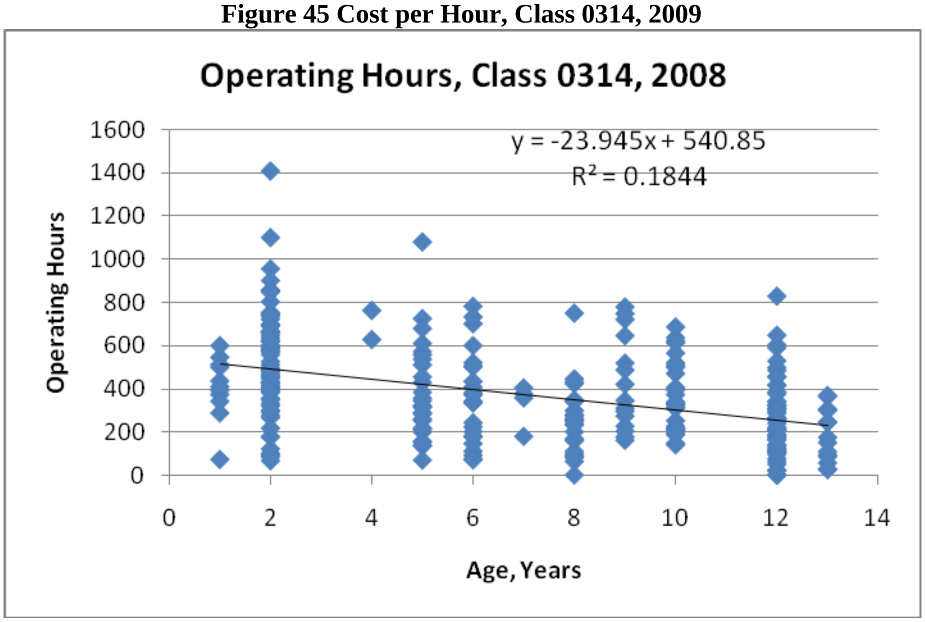

Figure 46 Operating Hours by Age, Class 0314, 2008

4.5 Class 0900– Motor Grader

Table 60 shows that class 0900 motor grader average cost per hour has generally been trending up since 2007, discounting the particularly high value in 2006. Figure 47 plots the cost per hour for 2009 and estimates an increase of 4.83% per year from the base of $19.88 per hour. Figure 48 indicates a historical pattern of a 28 hour per year decline in operating hours starting from a base of 643 hours.

Table 60 Average Cost per Mile, Class 0900, $2009

	2006	2007	2008	2009

Cost per hour	$51.42	$35.35	$43.21	$37.50

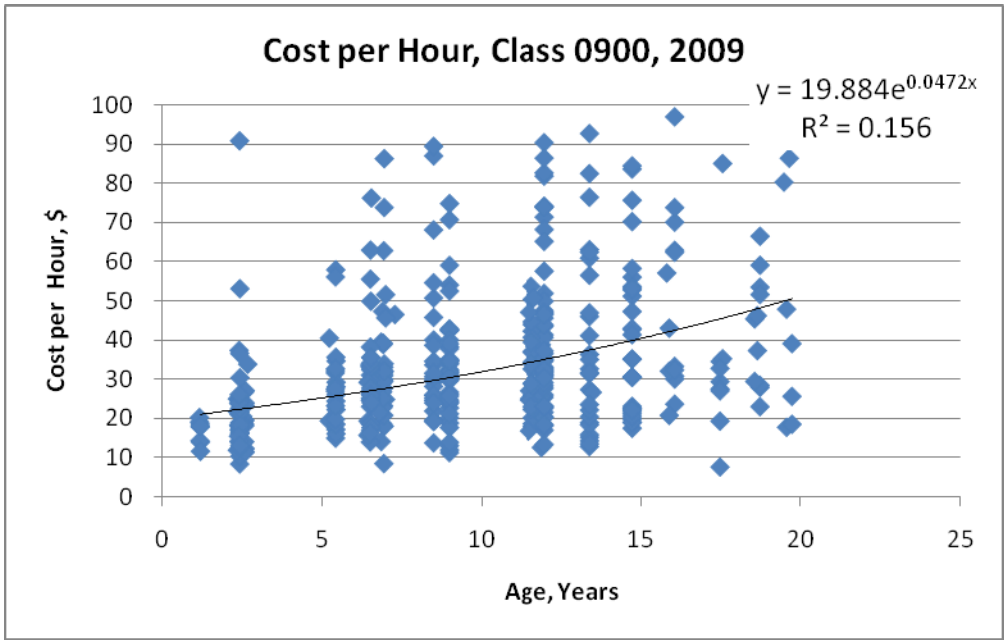

Figure 47 Cost per Hour, Class 0900, 2009

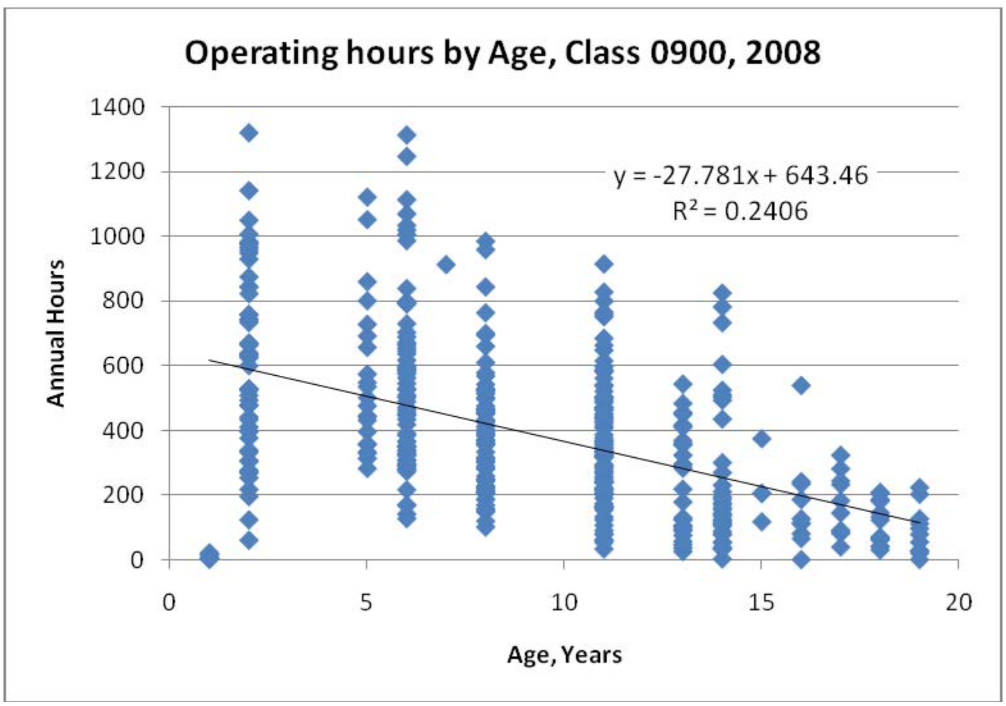

Figure 48 Operating Hours by Age, Class 0900, 2008

4.6 Class 2002 – Front End Loader

Table 61 presents the average cost per hour of the class 2002 front end loader fleet and does not demonstrate a consistent trend for the four years of data. Figure 46 estimates a 4.6% increase per year in the cost per operating hour starting from a base cost of \$15.76 per hour. Figure 50 shows an 18.1 hour annual decline in operation from the base of 461.

Table 61 Average Cost per Mile, Class 2002, \$2009

	2006	2007	2008	2009
Cost per hour	\$52.71	\$32.33	\$45.21	\$35.20

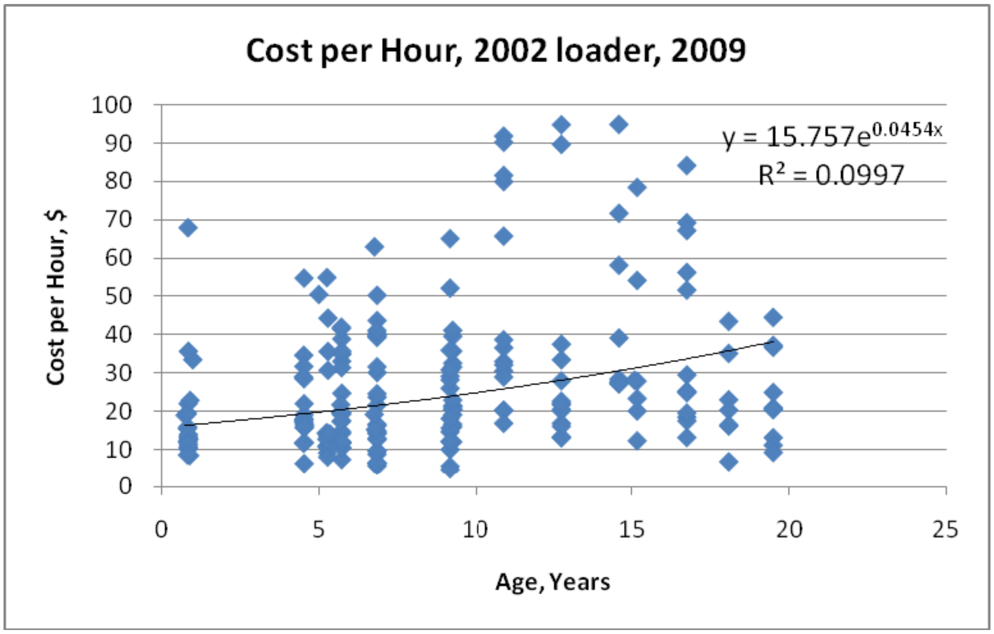

Figure 49 Cost per Hour, Class 2002, 2009

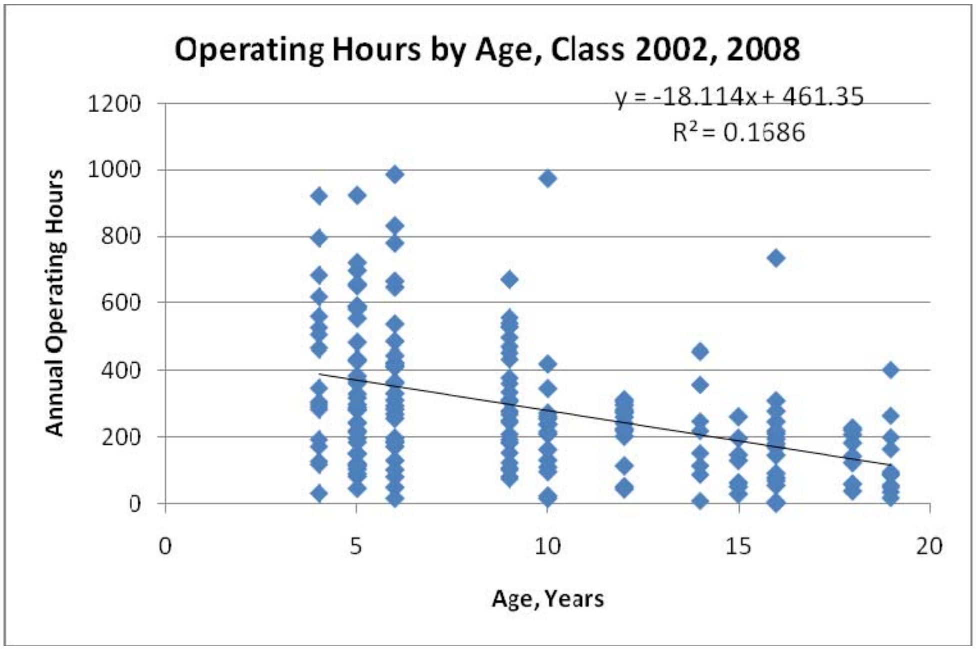

Figure 50 Operating Hours by Age, Class 2002, 2008

4.7 Summary – Cost and Usage Trends

This chapter examined trends in operating cost and use patterns by age for the six classes. Table 62 summarizes the operating cost increase for all four years highlighting in bold the 2009 data, which was the focus of this chapter. As noted earlier in this report, 2006 was the first year SAP was introduced and there are erratic patterns in the data set we obtained. However, this is another reason to select the 2009 data on operating cost as the most accurate and representative values, representing the current state of the fleet.

Table 62 Summary of Annual Operating Cost Increase

	0201	**0205**	**0206**	**0206***	**0314**	**0900**	**2002**
2006	4.53%	8.09%	6.88%	5.41%	6.84%	5.59%	7.68%
2007	0.74%	4.09%	2.07%	0.40%	6.55%	4.17%	4.52%
2008	1.97%	4.91%	2.27%	1.60%	5.90%	3.91%	4.49%
2009	**7.17%**	**7.37%**	**5.76%**	**5.47%**	**8.10%**	**4.83%**	**4.64%**

* This column contains flatbed trucks only (i.e. "TRUCK2" as designated in SAP). Special purpose trucks with special attachment such as towing, aerial, sprayers, etc. are not included.

Table 63summarizes the base values identified in the operating cost equations.

Table 63 Base Values for Operating Cost

	Cost per mile			Cost per hour		
Class	0201	0205	0206	0314	0900	2002
Base cost ($)	0.17	0.61	0.56	12.72	19.88	15.76

Relative to usage trends, there is a consistent decline in use with age as evidenced by the 2008 data, the last full operating year considering the budget issues of 2009. Table 64 summarizes the forecast models identified for each class, using linear equations.

Table 64 Summary of Decline in Use Values

	Miles per year			Hours per year		
Class	0201	0205	0206	0314	0900	2002
Base	14,710	12,650	7,944	541	643	461
Annual decline	529	539	226	24	28	18

The values in Tables 62, 63, and 64 represent the base cases, representing current usage patterns. Considering the impact of the recommended fleet reductions, the optimal cost model will adjust these values per the reallocation of usage resulting from the smaller, higher utilized fleets for the six classes. In general, we estimated these adjustments (cost per mile, annual increase in operating cost, and annual miles or hours) at approximately 10% and this will be discussed in more detail in Chapter 5.

5 Optimal Life Cycle Cost Models

This chapter applies the relationships and data from the previous chapters to examine the optimal life cycle for each of the six classes. It begins with an overview of life cycle models, examines sensitivity issues, discusses the specific data which is integrated into the model, and then uses the optimal life model to identify a target retirement period for each class.

Engineering economics employs a number of models for equipment replacement studies such as this. Most involve the concept of a challenger (a new or updated replacement) and a defender (the current asset or model) with the decision question focusing on when and if to replace an old asset (defender) with one or more alternatives (challengers). A fundamental concept in these models involves the economic life of an asset. The economic life defines the operating interval which minimizes the equivalent uniform annual cost (EUAC) of the asset. A key strength in this approach is that both new and existing assets are compared based on their optimum economic lives. In addition, these models can be updated on a periodic basis as new or improved economic data on the challenger and defender becomes available. This assures thorough and ongoing evaluation of improvement opportunities. We have selected the challenger-defender framework since it provides a flexible foundation for the current and future asset decisions which may face NCDOT management.

The primary principle of the challenger- defender model is that the defender should be kept as long as the marginal cost of one more year of life is less than the EUAC of the challenger over its economic life. The analytical approach involves development of a total cost model which reflects cost factors which are significant in economic impact and important to decision makers. In the case of the six classes, the challenger is a new unit with equivalent capabilities but with improved operating cost and the challenger- defender framework can be simplified to an optimal economic life analysis.

5.1 Optimal Life Model Description

Figure 51 demonstrates the basic principle of optimal life models. The total cost curve (at the top) is comprised of the sum of two components: the capital cost and operations and maintenance cost. As time, use, or age of the current asset progresses, the total asset cost declines initially. In this first part of asset life (left half of Figure 51), capital cost declines on an annual basis as asset life is spread over more years. On the other hand, the cost of operation and maintenance (O&M) becomes more expensive but does not override the decline in capital. As the asset continues to age (right half of Figure 51), O&M cost increases begin to outstrip the decline of capital cost. The point where the total cost reaches a minimum is the optimal economic life of the asset and the point at which it should be replaced.

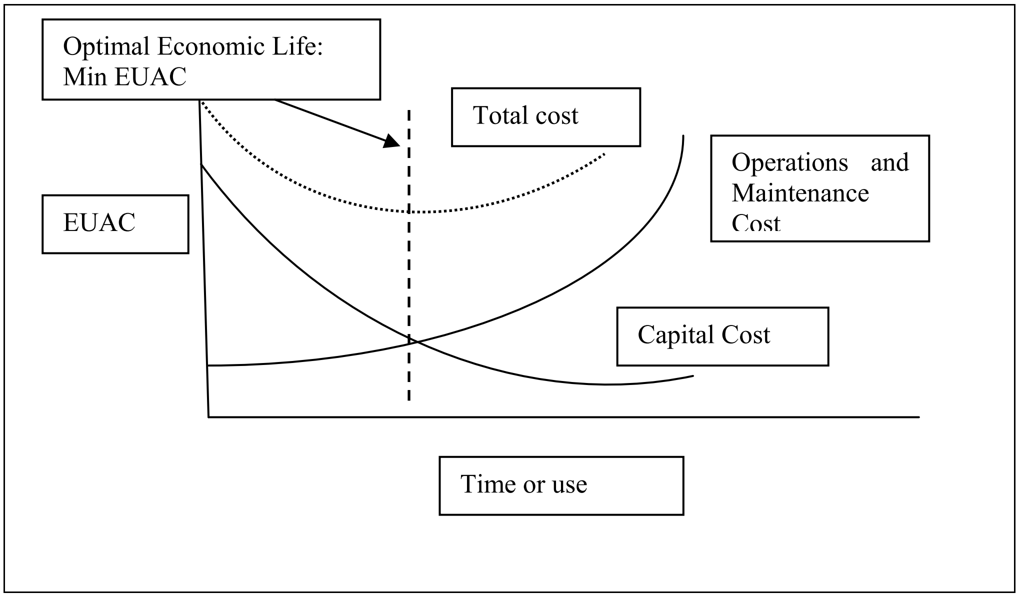

Figure 51 Graphical Example of Optimal Life Model

In general terms, Equation 9 defines the EUAC[9] of asset "x" (sometimes expressed as the annual cost) as the sum of annual expense terms, such as maintenance and operating costs, plus the capital recovery expense incurred by keeping the equipment.

EUACx= (annual O&M and related expenses) + (CR: capital recovery cost) **Equation 9**

CR, the capital recovery cost, is calculated in Equation 10 with P = the present market value and S = the salvage value

$$CR = P\ (A/P, i\%, n) – S\ (A/F, i\%, n)$$ **Equation 10**

Capital Recovery cost (CR) represents the difference between current market values and salvage and becomes less as the unit ages. Terms such as (A/P, i%, n) represent the standard engineering economic factors to convert values to present (P), future (F) , or annual worth (A) amounts based on a given interest rate (i%) and the number of compounding periods (j, k, or n).

The optimal life model we will employ builds on the basic EUAC Equation 9 using a year by year, iterative approach which can be reevaluated annually as new information is identified. To demonstrate the application of this methodology, we present an example of calculating the EUAC in a specific year of an asset. On a before tax basis, the present worth of a new asset through year k in the future is described by Equation 11:

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9 Additional information on EUAC and annual cost can be found in Canada, John, William Sullivan, Dennis Kulonda, and John White. *Capital Investment Analysis for Engineering and Management, 3rd Edition*. Prentice Hall, New York, 2005, p.144 and pp. 274-291.

$$PW_k = I\text{-}MV_k(P/F, i\%, k) + \sum_{j=1}^{k} E_j (P/F, i\%, j) \qquad \textbf{Equation 11}$$

where I = initial capital investment, MV = market value at the end of year k, and the summation is the total of the annual operating and maintenance expenses (Ej) from the current year to year k in the future.

The total marginal cost of an incremental year of ownership is a critical quantity for the optimal life decision. Using equation 11, the difference in present value of the marginal cost of an additional year of ownership from year (k-1) to year k can be developed using Equation 12.

$$TC_k\ (i\%) = MV_{k-1} - MV_k + i^*MV_{k-1} + E_k \qquad \textbf{Equation 12}$$

MV = market value in the year of interest and E = annual expenses incurred in the year of interest. Using this equation, EUAC can be calculated using Equation 13.

$$EUAC_k = \left[\sum_{j=1}^{k} TC_j \left(\frac{P}{F}, i\%, j\right)\right]\left(\frac{A}{P}, i\%, k\right) \qquad \textbf{Equation 13}$$

Table 65 shows the spreadsheet application of these equations for a set of parameters (noted in Table 66) for class 0201 pickup trucks. For a given year and using the column numbers on the bottom line, the following bullet points describe the column content:

- Column 1 (market value): represents the anticipated market value in a given year. In year 3, this asset is anticipated to have a market value of $13,956 from its original purchase price of 19,239.
- Column 2 (Loss in MV): Calculates the incremental loss in MV for keeping the asset one more year. For example, MV declines from $17,287 to $15,533 from year 1 to 2 for a loss in MV of $1,952.
- Column 3 (Capital cost of MV): The cost of maintaining the investment in the asset and not liquidating is the interest rate (in this case 3%) times the market value. For example, in year 2, $15,533*3% = $466.
- Column 4 (Miles): This is the anticipated usage of the asset in miles or hours.
- Column 5 (Annual Operating Expense): This column multiplies the anticipated cost per mile for specific year times the annual miles. For year 2, the estimated cost per mile is approximately $0.20.
- Column 6 (Total marginal cost): This column sums columns 2, 3, and 5 to calculate the total marginal cost of an incremental year of asset use.
- Column 7 (PV of marginal cost): This column takes the marginal cost in column 6 to a present value at the time of asset purchase. For example, the present value of $5,210 at 3% and 2 years is $4,911.
- Column 8 (Total PV): This column adds the PV values for the previous years from column 7. For example for year 2, $10,069= $5,158 +$4,911.

- Column 9 (EUAC): Column 9 converts the total PV in column 8 to a series of uniform annual costs. For example the equivalent uniform annual cost of a present value of $10,069 at 3% for two years is two equal payments of $5,262.

The minimum EUAC can be seen in year 8, highlighted in bold. As noted in Table 66, we estimated the optimal life for this asset class between 8 and 9 years since we believe this asset class will have greater annual miles and less decline over time (from the reduction of the fleet) than the conservative reallocation shown in column 4 of Table 65.

Table 65 Example of Optimal Life Calculation

Year	Market Value	Loss in MV	Capital cost of MV	Miles	Annual Oper. Expense	Total marginal cost for year	PV of marginal cost	Total PV	EUAC through current year
0	$19,239			15,710					
1	$17,287	$1,952	$519	15,234	$2,842	$5,313	$5,158	$5,158	$5,313
2	$15,533	$1,754	$466	14,758	$2,990	$5,210	$4,911	$10,069	$5,262
3	$13,956	$1,576	$419	14,282	$3,142	$5,137	$4,701	$14,771	$5,222
4	$12,540	$1,416	$376	13,806	$3,299	$5,091	$4,523	$19,294	$5,191
5	$11,268	$1,273	$338	13,330	$3,459	$5,069	$4,373	$23,667	$5,168
6	$10,124	$1,143	$304	12,855	$3,622	$5,069	$4,245	$27,912	$5,152
7	$9,097	$1,027	$273	12,379	$3,788	$5,088	$4,137	$32,049	$5,144
8	**$8,174**	**$923**	**$245**	**11,903**	**$3,955**	**$5,123**	**$4,044**	**$36,093**	**$5,142**
9	$7,344	$829	$220	11,427	$4,123	$5,173	$3,965	$40,058	$5,145
10	$6,599	$745	$198	10,951	$4,291	$5,234	$3,895	$43,953	$5,153
Col. #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

5.2 Sensitivity of Optimal Life Model to Parameter Changes

In exploring the optimal life of the six asset classes, we examined the impact of data uncertainty and variability on the model results. Examples of model variables and their impact include:

- Increasing the O&M costs decreases the optimum life interval. There are several factors impacting O&M including the rate of increase of annual costs, the rate of decline in use with age, and the starting usage base level. We explored all of these.
- Increasing the initial investment increases the optimal replacement interval. We did not explore this factor since the values we have for initial cost closely reflect actual data and there is no reason to believe these values will significantly change in the future.
- Increasing the rate of return increases the replacement interval. Based on econometric forecasts, there is no anticipation that current interest rates will change significantly in the next several years.
- Increasing the rate of decrease in salvage tends to increase the optimum replacement interval. We explored possible changes in the rate of market value decline.

Our approach in sensitivity analysis employed three components.

- Base scenario: As a foundation, we searched for the optimal life using the base scenario information which has been developed in chapters 2, 3, and 4. In general, this scenario represents current levels of use and operation.
- One at a time changes: We examined variable changes one at a time in 10% change steps from the base values, either increase or decrease as appropriate. This step included rate of decline in market value, the rate of decline of use with age, rate of increase of

operating cost and base miles or hours of use. One at a time sensitivity analysis provides insight as to which parameters have the largest impact on optimal life.

- Most Likely - Several variables changing together: Based on our recommendations for fleet size adjustments, this is the scenario reflecting the anticipated future. For example, if the fleets are reduced and utilization increases, this will impact the starting usage level (increase), the rate of decline of usage over time (smaller), and the acceleration of higher operating cost (increase) compared to the base scenario. The results discussed in the next section reflect the results of the most likely scenario, using the model variables outlined in Table 66.

5.3 Optimal Life Model Results

Per Table 66, the model predicts the estimated economic life for the six classes as:

- Class 0201-Pickup Truck: Optimal economic life identified in the 8-9 year range.
- Class 0205-Dump Truck: Optimal economic life identified in the 8 year range.
- Class 0206-Flat Bed Truck: Optimal economic life identified in the 8-9 year range
- Class 0314 Loader Backhoe: Optimal economic life identified in the 8 year range.
- Class 0900 Motor Grader: Optimal economic life identified in the 11 year range.
- Class 2002 Front End Loader: Optimal economic life identified in the 12 year range.

As noted, the data columns in Table 66 indicate the values employed in the economic life model as adjusted from current operational practice, anticipating the proposed fleet reductions. It is important that this model and its parameters are consistently and periodically examined and updated based on updated NCDOT SAP cost and market data. The results should serve as a foundation for identifying the best replacement cycles for these classes and save significant NCDOT costs.

The equipment replacement budget should be evaluated with these life cycles in mind with the goal that no unit in the fleet exceeds these targets by more than two years. We anticipate that much of the extremely old equipment will be disposed based on the recommendations related to increased utilization. However, going forward, it will be important to fund replacement on a consistent basis so that additional costs are not incurred.

Table 66 Economic Life Summary

	Interest rate	Market value base	Market value annual decline rate	Base annual miles / operating hours	Annual miles / operating hours decline	Base cost per mile/ hour	Annual increase in cost per mile / hour	Results
Class 0201	3%	$19,239	10%	15,710 miles	475 miles	$0.17	7.9%	Optimal economic life identified at 8-9 years
Class 0205	3%	$51,853	11%	13,915 miles	431 miles	$0.61	8.1%	Optimal life identified at 8 years.
Class 0206 (truck 2)	3%	$52,130	9%	9,533 miles	181 miles	$0.58/ mile	6.9%	Optimal economic life identified at 8-9 years
Class 0314	3%	$71,574	8%	595 hours	21.6 hours	$12.72	8.9%	Optimal life identified at 8 years.
Class 0900	3%	$154,030	8%	836 hours	19.6 hours	$19.88	6.3%	Optimal life at 11 years
Class 2002	3%	$107,364	8%	599 hours	10.6 hours	$15.76	6.0%	Optimal life at 12 years

6 Summary and Recommendations

The primary goals of this study were to determine, for six classes of equipment (the largest NCDOT groupings: pickup trucks, single axle dump trucks, flat bed and miscellaneous, loader-backhoe, motor grader, and front end loader), a methodology for evaluating aging (or depreciation), disposal points, and overall utilization. To accomplish these objectives, this report examined four years of data related to utilization and cost and examined external data involving salvage and market values of aged equipment. This information was integrated into an optimal life model to determine the life cycle for these six equipment classes which yielded the minimum equivalent uniform annual cost. The following sections review key issues identified in Chapters 2-5.

6.1 Chapter 2 Summary and Recommendations

This chapter examined utilization cost and age information for the six equipment classes. Over the four year period of the study, the average age characteristics of these six classes increased and age is a significant issue for the long term. The primary recommendation involved removal of equipment with utilization less than 20% and development of a segmented strategy for classifying equipment and utilization targets based on primary need. We proposed an equipment category with a mission to support ongoing, consistent, day to day operations. This equipment group should generally produce annual utilization rates higher than 70%. The second category encompasses pooled requirements to address inconsistent or spare needs. In general, this group should yield average utilizations above 30%. The composite utilization of both of these groupings will produce minimum class utilization targets above 50%. A third class is possible and this relates to emergency needs which cannot be effectively covered by the first two classes. If this class is needed, the equipment in it should be periodically reviewed and utilization targets will need to be individually addressed.

Discussions with project contacts in the divisions and with the project team identified a number of potential steps to implement this plan and increase utilization.

- Identify the impact of the current operational mission on the work which can be consistently executed by NCDOT personnel based on the anticipated budget and manpower. It is clear that this point has resulted in decisions to retain equipment as a means of managing uncertainty about these key operational factors.
- Based on the results of the previous point, segment fleet size and utilization targets based on the consistently needed work (and the recommendations in this chapter) to enhance asset utilization. Equipment to support consistent, day to day operations should be modern, reliable, and highly utilized.
- Identify the work which is sporadic or inconsistent and explore alternative approaches for sourcing equipment to support these needs.
- Critically evaluate the need for spare or pooled equipment and how pools or rentals could be effectively developed to support this need.
- Based on sporadic and spare needs, identify the needed equipment levels and the target utilizations.

From an organizational perspective, these directions will also entail inter and intra division considerations:

- The importance of charging the vehicle for the entire time it is committed to use is critical. It is clear that this is causing understated utilization.
- The importance of considering divisional rental rates so the impact of local decisions is more readily apparent and beneficial.
- At the division level, consideration of ways to share vehicles between operating groups or department boundaries, such as maintenance and construction. For example, there are intervals between award or construction project phases which have detrimental impact on pickup truck utilization. Ways to share between operating groups would help this and other class utilization
- Development of an administrative fleet of trucks which could be centrally managed to help pool the ebb and flow of seasonal usage. Potential rental opportunities are also possible.
- Identification and sharing of best practices to address seasonal needs such as when summer students or part time inspectors are hired.

6.2 Chapter 3 Summary and Recommendations

This chapter developed estimates for each of the six classes of current purchase prices and how the market value of these assets decline over time with use. Exponential decay equations were fitted to the best information available from the NCDOT historical salvage database, web pricing guides, and commercial auction services that maintain several years of historical information. The exponent in these equations was then converted to identify annual percentage declines in value.

The decline rates identified represent a bracket for the actual rate of decline NCDOT equipment will experience using a consistent and periodic equipment replacement approach, based on an optimal economic life. On the low end, the NCDOT rate represents very used, old equipment between ten and twenty years old, with questionable remaining life from the purchaser's perspective. On the high end, the market price column represents the value decline of used equipment with a more reliable remaining service life to the purchaser, generally representing newer equipment with significant remaining life. We selected decline rates which were realistic starting points for the economic life model based on the chapter findings. It will be important over time to continue to refine this information as disposals occur and we continue to gather annual information on equipment disposal values.

6.3 Chapter 4 Summary and Recommendations

This chapter examined operating cost and use patterns for the six classes and how these parameters vary with equipment age, two critical components of the optimal life model. The first component examined was annual operating costs and this was evaluated on a cost per-mile (classes 0201, 0205, 0206) or cost per-hour (classes 0314, 0900, 2002) basis, using data from the SAP system for the 2006-2009 period. Operating cost was calculated as the sum of the PM labor, repair labor, PM parts, repair parts, parts, fuel, oil, and tires. This sum was divided by the number of miles (for on road) or operating hours (for off road) to develop an annual operating cost for each asset. For each year of study data, the annual operating cost per mile or cost per hour was plotted versus the age of the item and best fit descriptive equations were investigated.

The second critical optimal life component discussed in this chapter was the pattern of usage variation with age over the life of the asset. The best performance of the optimal life model results if equipment is used consistently throughout its life. This is not now the case and may take several years to accomplish this goal. Consequently, we identified the current usage –age pattern so it could be integrated into the optimal life model. As time progresses and the collaborative efforts to improve fleet utilization produce results, we anticipate these usage patterns will be more consistent over asset life. Consequently, we selected 2008 data as the best example of current usage patterns. This will need to be tracked as utilization improves and fleet size changes over the next several years.

The chapter identified that annual operating cost increases ranged from 4.64% for the class 2002 motor grader to 8.1% for the class 0314 loader-backhoe. Annual operating cost per mile (including the cost items noted above) for on road items ranged from $0.17 for pickup trucks to $0.61 for dump trucks and from $12.72 per hour for loader- backhoes to $19.88 for motor graders. Finally we identified the annual declines in usage with age varied from 226 miles per year for the class 0206 truck2 to 539 miles per year for the 0205 dump truck and from 18 hours per year for the class 2002 loader to 28 hours per year for the motor grader.

6.4 Chapter 5 Summary and Recommendations

This chapter applied the relationships and data from the previous chapters to examine the optimal life cycle for each of the six classes. A fundamental concept in these models involves the economic life of an asset, defined as the operating interval which minimizes the equivalent uniform annual cost (EUAC) of the asset. A key strength in this approach is that both new and existing assets are compared based on their optimum economic lives. In addition, these models can be updated on a periodic basis as new or improved economic data on the challenger and defender becomes available. This assures thorough and ongoing evaluation of improvement opportunities and provides a flexible foundation for the current and future asset decisions which may face NCDOT management.

The model predicts the estimated economic life for the six classes as:

- Class 0201-Pickup Truck: Optimal economic life identified in the 8-9 year range.
- Class 0205-Dump Truck: Optimal economic life identified in the 8 year range.
- Class 0206-Flat Bed Truck: Optimal economic life identified in the 8-9 year range
- Class 0314 Loader Backhoe: Optimal economic life identified in the 8 year range.
- Class 0900 Motor Grader: Optimal economic life identified in the 11 year range.
- Class 2002 Front End Loader: Optimal economic life identified in the 12 year range.

The values employed in the economic life model reflect the most likely estimate of usage patterns and activity levels, anticipating the proposed fleet reductions. It is important that this model and its parameters are consistently and periodically examined and updated based on updated NCDOT SAP cost and market data.

The equipment replacement budget should be evaluated with these life cycles in mind and the goal that no unit in the fleet exceeds these targets by more than two years. We anticipate that much of the extremely old equipment will be disposed based on the recommendations related to increased utilization. However, going forward, it will be important to fund replacement on a consistent basis so that additional costs are not incurred.

7 Appendices

Appendix A Annotated Bibliography

In the first part of the study, a thorough search of relevant literature was conducted and this section provides information on the most cogent documents and articles we found. Although these are important references, this study was unique in that we could not find a parallel work complete by another state DOT.

Literature Search Summary

During the literature search, our task was to develop a list of potential reference sources to offer support for the research. The first step was to formulate a list of keywords that could be manipulated during the search to procure different results. The list is attached following this summary. These words were entered into several databases to identify relevant material. These databases include Compendex, Applied Science Full Text, Science Direct, JSTOR, and Geobase. Additional material was found by examining the references of an already accepted source. Once a potential source document was located, the citation and abstract was reviewed to determine the relevance of the material. If the material was deemed pertinent to the study, the full text was acquired and an annotated bibliography entry was written for each reference item.

Keyword List

The following keywords were employed in the data base searches:
Vehicle replacement, Transportation replacement, System life cycle cost, Cost responsibilities, Post-Manufacturing Product Cost (PMPC), Ownership costs, Operating costs, Motor Carriers, Equipment replacement, Optimization model, Transportation, Vehicle Utilization, Replacement, Strategic planning, Integer programming, Cost management, Repair limit, Fleet management, Depreciated life, Disposal points, Utilization rates, Operational and Maintenance Costs, NCDOT, Cost effective life, Equipment maintenance, Cost equipment lifecycle, Integrated operational cost, Depreciation, Replacement analysis, Economic life, Salvage values, Equipment Age, Operational hours, Sudden failure, Failure rates, Capital recovery, Vehicle fleet, Cost effectiveness, Vehicle maintenance, Construction/construction equipment, Engineering economics, and vehicle retirement

Annotated Summary of Resource Documents

Bell, R., Mioduski, R. (1976). Extension of life of u.s. army trucks. Proceedings of the Annual Reliability and Maintainability Symposium, 200-205.

The U.S. Army maintains use of ¼, 2 ½, and 5-ton payload vehicles. This study has two purposes. The first is to determine the age at which it is best to replace the vehicles entirely and the second is to determine the overall economical effectiveness of overhauling the vehicles in order to extend the life of the fleet. The paper also describes the current accomplishments of the study as well as ongoing work. The results of the study suggest that it is possible to economically extend the life of the vehicles under consideration in the study.

Chan, C.L., & Miller, F.G. (1989). Optimization of fleet component exchange using the age replacement strategy. Maintenance Management International, 7(3), 155-163.

Public transit systems often times employ a "replace at failure" policy. This study demonstrates what they call the Age Replacement Strategy. This methodology employs mathematics to predict the age (mileage) of failure of specific components. The process is determined by determining how the costs vary at different mileages with inflation taken into account and is then compared to the "replace at failure" method. The results demonstrate that the Age Replacement Strategy is an effective tool to decrease maintenance costs.

Chee, P.C.F. (1975). Practical vehicle replacement for Ontario Hydro. Ontario Hydro Research Quarterly, 27(3), 3-6.

Ontario Hydro employed several vehicle replacement strategies; however this study determines that a different method is necessary. The article demonstrates a two-part method in order to choose vehicles for replacement. First, a General Fleet Replacement Analysis is conducted to determine the economic life of a range of vehicles, and then a Repair Limit Analysis is manipulated to determine the effectiveness of repairing a specific vehicle.

Chen, S., & Keys, L.K. (2009). A Cost analysis model for heavy equipment. Computers and Industrial Engineering, 56(4).

A general mathematics Post-Manufacturing Product Cost (PMPC) model is developed to evaluate the total cost of heavy machinery by utilization stage. The model was created in order to expand the manufacturers' cost capacity to include the post-manufacturing costumer stage of their product.

Davenport, N.S., Anderson, M.D., & Farrington, P.A. (2005). Development and application of a vehicle procurement model for rural fleet asset management. Transportation Research Record, 1927, 123-127.

This article describes the design and application of a vehicle procurement model designed for the Alabama Department of Transportation. This model predicts vehicle serviceability by manipulating socioeconomic and vehicle usage data. Application of this system assists with the estimation of fleet quality, identify vehicles in need of replacement in a given year, aid in the management of the fleet, and assist in predicting future funding and other needs.

Eilon, S., King, J.R., & Hutchinson, D.E. (1966). A Study in equipment replacement. Operational Research Society, 17(1), Retrieved from http://www.jstor.org/stable/3007240

Two types of forklift trucks were examined to find an optimum replacement model. This model was defined by taking into consideration of capital allowances for tax purposes, an optimum range of equipment life in replacement policy instead of a single value of economic life, and the effect of technical changes in design.

Fan, H., Kim, H., & Zaïane, O.R. (2006). Data warehousing for construction equipment management. Canadian Journal of Civil Engineering, 33(12), 1480-1489.

This paper demonstrates an equipment data warehouse and a prototype decision support system. This system allows managers to visually evaluate the vehicle fleet from different perspectives and details. The system assists equipment logistics, supplies, maintenance, repair, and replacement.

Gillespie, J. S., & Hyde, A. S. (2004). The replace/repair decision for heavy equipment. Charlottesville, VA: Virginia Transportation Research Council. 1-44.

This report focuses on timely replacement of vehicles in order to decrease operational and maintenance costs and increase overall savings for the Virginia Department of Transportation (VDOT). The main goal of this study is to evaluate several cost forecasting equations.

Hanson, R.A., & Kyte, C.A. (1999). An Investigation of rental rates for centralized fleet vehicles. Virginia Transportation Research Council, 1-20.

This report investigates the rental rate structure manipulated by the Division of Fleet Management to charge state agencies, like the Virginia Department of Transportation, who was the client of the study, for the use of centralized vehicles. In this paper, the researchers compiled a literature review, and analyzed data from Fleet Management as well as compiling regression analysis to create a new system of replacement criteria and new rental rates.

Hastings, N.A.J. (1969). The Repair limit replacement method. Operational Research Society, 20(3), Retrieved from http://www.jstor.org/stable/3008736

The paper focuses on two main problems: the equipment's condition related to age and condition related to the amount of major repairs the item has received. These problems as well as other factors, which could alter the decision on replacing or repairing, equipment availability, introduction of new equipment, etc, are discussed and used to develop a new model.

Kahsnabis, S. (2003). Asset management framework for state departments of transportation to meet transit fleet requirements. Transportation Research Record, 1835, 74-83.

In this article, an asset management framework is discussed so that state departments of transportation can perform several tasks. The proposal contains two models. One model serves the purpose of maximizing fleet life of purchased buses within the budget of the group employing the framework. The other is to maximize the fleet life of already existing and rebuilt buses in the group.

Kim, D. S., Porter, J. D., Kriett, P., Mbugua, W., & Wagner, T. (2009). Fleet replacement modeling final report. School of Mechanical, Industrial and Manufacturing Engineering, Oregon State University. 1-177.

This study was performed for the Oregon Department of Transportation (ODOT). It had two main purposes. The study evaluated the assumption that all similar assets are equally utilized. It also developed a fleet condition model for ODOT.

Kriett, P. O. (2009). Equipment replacement prioritization measures: simulation and testing for a vehicle fleet. (Master of Science Thesis, Oregon State University, 2009).

This report is a thesis written by Kriett to assist the Oregon Department of Transportation (ODOT) with its current vehicle fleet. The development of a model to simulate the operation of various equipment types was performed during the study

Love, C.E., Rodger, A., & Blazenko, G. (1982). Repair limit policies for vehicle replacement. INFORMS Journal, 20(2), 226-236.

This study describes two replacement policies for vehicle fleets. One is a replacement policy in which vehicles are replaced at a set age. The second policy employs a repair limit that is set that varies depending on the vehicle. So, in this case a vehicle is replaced when the cost of a given repair exceeds the boundary of the repair limit.

Mine, H., & Kawai, H. (1975). An Optimal inspection and replacement policy. IEEE Transactions on Reliability, 24(5), 305-309.

An optimal inspection and replacement policy is discussed. Units that are discussed are ones that assume a Markov state. The policy evaluation function is the s-expected cost-per-unit-time. The problem is a semi-Markov decision.

Nakagawa, Toshio, & Osaki, Shunji. (1974). The Optimum repair limit replacement policies. Operational Research Quarterly, 25(2), Retrieved from http://www.jstor.org/stable/3008372

In this study, the equipment is used until repair is needed. When a unit fails, the repair costs is estimated and determined whether it should be replaced or repaired. If the time of the repair exceeds the fixed repair limit time then a new unit replaces the broken one. A repair limit replacement model was created to minimize costs per unit of time for an infinite time span under suitable conditions.

Redmer, A. (2009). Optimisation of the exploitation period of individual vehicles in freight transportation companies. Transportation Research Part E: Logistics and Transportation Review, 45(6), doi: http://dx.doi.org/10.1016/j.tre.2009.04.015

A mathematical model was developed to determine specific vehicles replacement for freight transportation companies. The model focuses on the intensity of utilization of the vehicles and considers the economical criteria for vehicle replacement. Data obtained to determine the model parameters were: age, current cumulative mileage, an average maximum mileage to overall, an average annual mileage, load capacity, technical conditions, an average cost, and fuel consumption.

Redmer, A. (2005). Vehicle replacement planning in freight transportation companies. Advanced OR and AI Methods in Transportation. Conference Proceedings of 10the EWGT Meeting and 16th MiniEURO Conference

In this study a mathematical model was created to define the optimal replacement policy for vehicles used in a freight transportation company. The focus of developing this model was to reduce costs and improve the fleet’s technical and economical conditions. This was done by collecting data from various vehicles and considering two strategies: replacement upon failure and precautionary replacement. The data obtained from the operating fleet ranged from 66 ordinary to specialized trucks, tractors, trailers and semi trailers varying in age, load capacity, technical condition, fuel consumption, etc.

Report on a fleet operations review for the Florida Department of Transportation. (2007). Gaithersburg, MD: Mercury Associates, Inc. 1-148.

The purpose of this study was to address several problems with the way the Florida Department of Transportation (FDOT) relative to replacement policy. According to this study, the main problem facing FDOT was the method in which they managed the replacement of vehicles in their vehicle fleet. The study addresses several problems and offers suggestions to improve the FDOT system.

Simms, B.W., Lamarre, B.G., Jardine, A.K.S, & Boudreau, A. (1984). Optimal buy, operate and sell policies for fleets of vehicles. European Journal of Operational Research, 15(2), 183-195.
This article discusses the specific fleet replacement problem of when to buy new buses and retire old ones. This problem is characterized by vehicles that perform different tasks as a function of age and is subject to several restraints. The problem discussed in this study is structured so that it can be solved with several techniques, including dynamic programming and linear programming.

Shapira, A. (2007). Systematic evaluation of construction equipment alternatives: case study. Journal of Construction Engineering and Management, 133(1), 72-85.
This paper presents an example of a model employing the analytical hierarchy process (AHP) approach. This model addresses the difficulties when facing a multifaceted process. This paper states that researchers may have an interest in the multi attribute-decision-making method for construction management problems.

Sherif, Y.S. (1982). Reliability analysis: Optimal inspection and maintenance schedules of failing systems. Microelectronics and Reliability, 22(1), 59-115.
This paper is a review of literature describing the inspection and maintenance of failing systems. Inspection and maintenance involves planned and unplanned actions that contribute to a system that retains or restores it to an optimal state. The goal of these schedules is to minimize downtime and perform operations at the lowest possible cost.

Suzuki, Y., & Pautsch, G.R. (2005). A Vehicle replacement policy for motor carriers in an unsteady economy. Transportation Research Part A: Policy and Practice, 39(5), Retrieved from http://www.sciencedirect.com/science/article/B6VG7-4FV9MF1-1/2/9d1bd93ceeee613de2414c650560b3ee
In 2004 the motor carrier industry experienced a decline in resale value and increase in insurance premiums. Due to these changes vehicle replacement policies needed to be reexamined. In this study a model was created and tested by using actual data obtained from a single motor carrier. The results suggested that the vehicles should use longer replacement cycles when resale values are low and that non-substantial insurance fluctuations should not affect vehicle replacement policies.

Tsimberdonis, A.I., & Murphee Jr., E.L. (1994). Equipment management through operational failure costs. Journal of Construction Engineering and Management, 120(3), 522-535.
This paper discusses operational failure costs (OCFs), as well as the usefulness in regards to equipment management. The study recognizes the variables of each piece of equipment and the importance of the equipment itself. This study also recognizes the importance of the equipment as a whole in regards to the overall projects the given company may be undertaking. The study also discusses the significance of equipment failure, examines the use of OCF as a decision support tool for purchasing, retiring, renting, and leasing; and evaluates operations plans.

Weissmann, J., Weissmann, A.J., & Gona, S. (2003). Computerized equipment replacement methodology. Transportation Research Record, (1824), 77-83.

This article describes a research project performed for the Texas Department of Transportation (TXDOT) in order to improve the method of which they replace and maintain the overall vehicle fleet. The method offered in this study takes advantage of the Equipment Operating System (EOS) that TXDOT already employs. The objectives of the research were to develop a computerized system that can update the analysis of data sets, process and compare the life cycle costs for the entire TXDOT inventory, support equipment replacement decisions with life cycle cost criteria, and create simple reports that can be easily and visually analyzed.

White, D.J. (1988). Repair limit replacement. Operational Research Spectrum, 11(3), doi: 10.1007/BF01720784

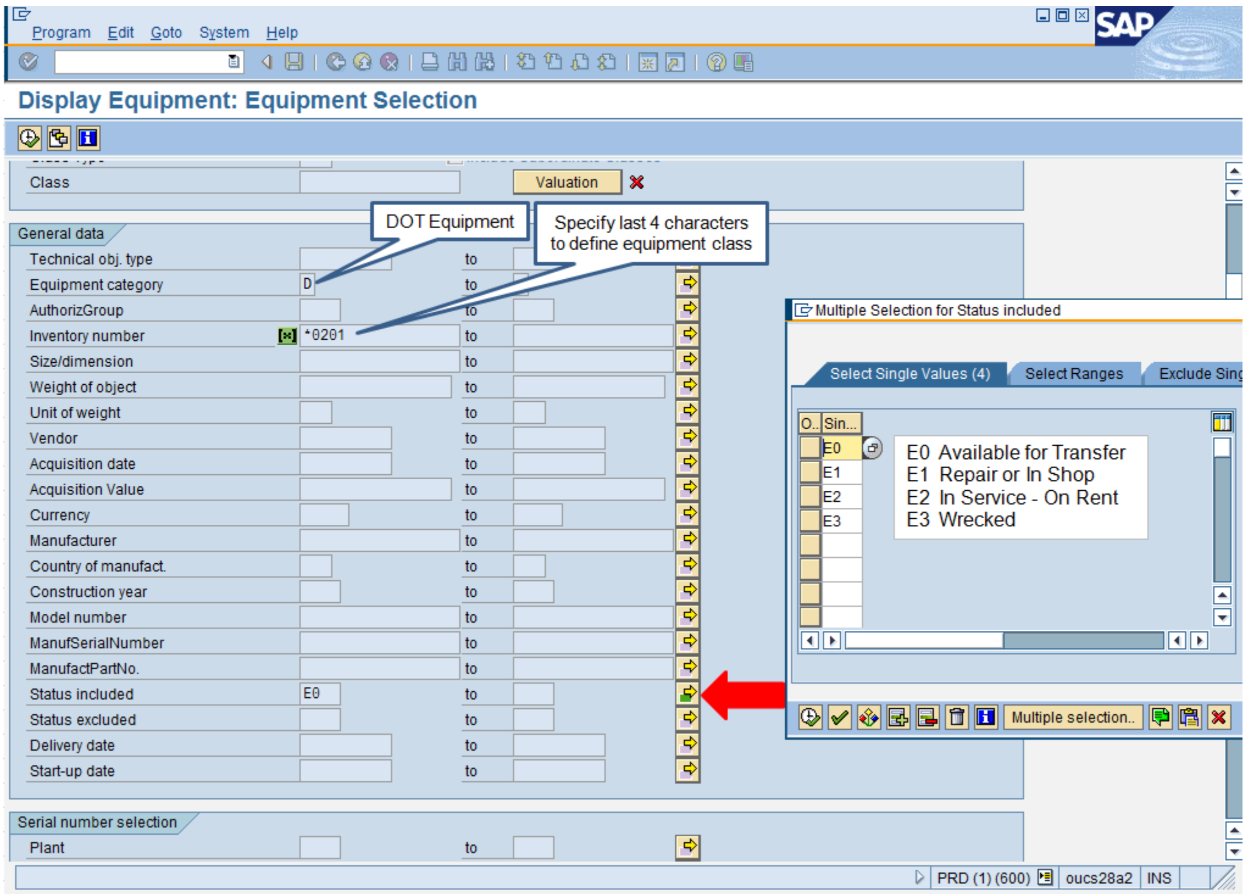
Studies have shown that repair limits decrease with age but it is also implied that at a specific age a vehicle should be replaced no matter the repair cost. The article addresses these theoretical issues involving repair limits for replacement problems to define an optimum repair limit replacement model.

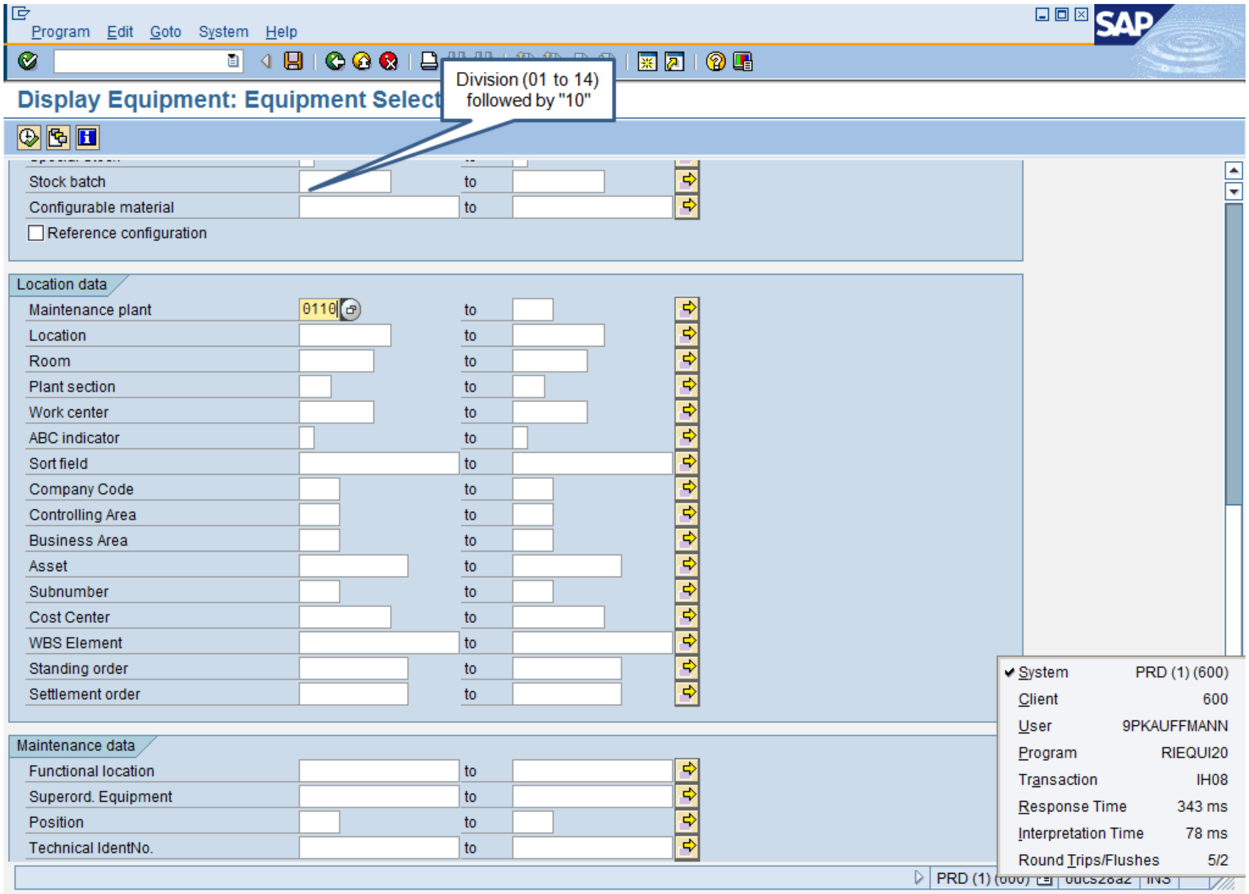
Wyrick, D. A., & Storhaug, B. J. (2003). Benchmarking fleet management. Deluth MN: Northland Advanced Transportation Systems Research Laboratories, University of Minnesota. 1-149.

This study consisted of two phases. The first phase consisted of several policies, organizational structure, and maintenance in several organizations. The second phase consisted of a nationwide study of a similar nature. Although the study showed that the Minnesota Department of Transportation (MnDOT), the study offers several recommendations to increase the effectiveness of the current processes.

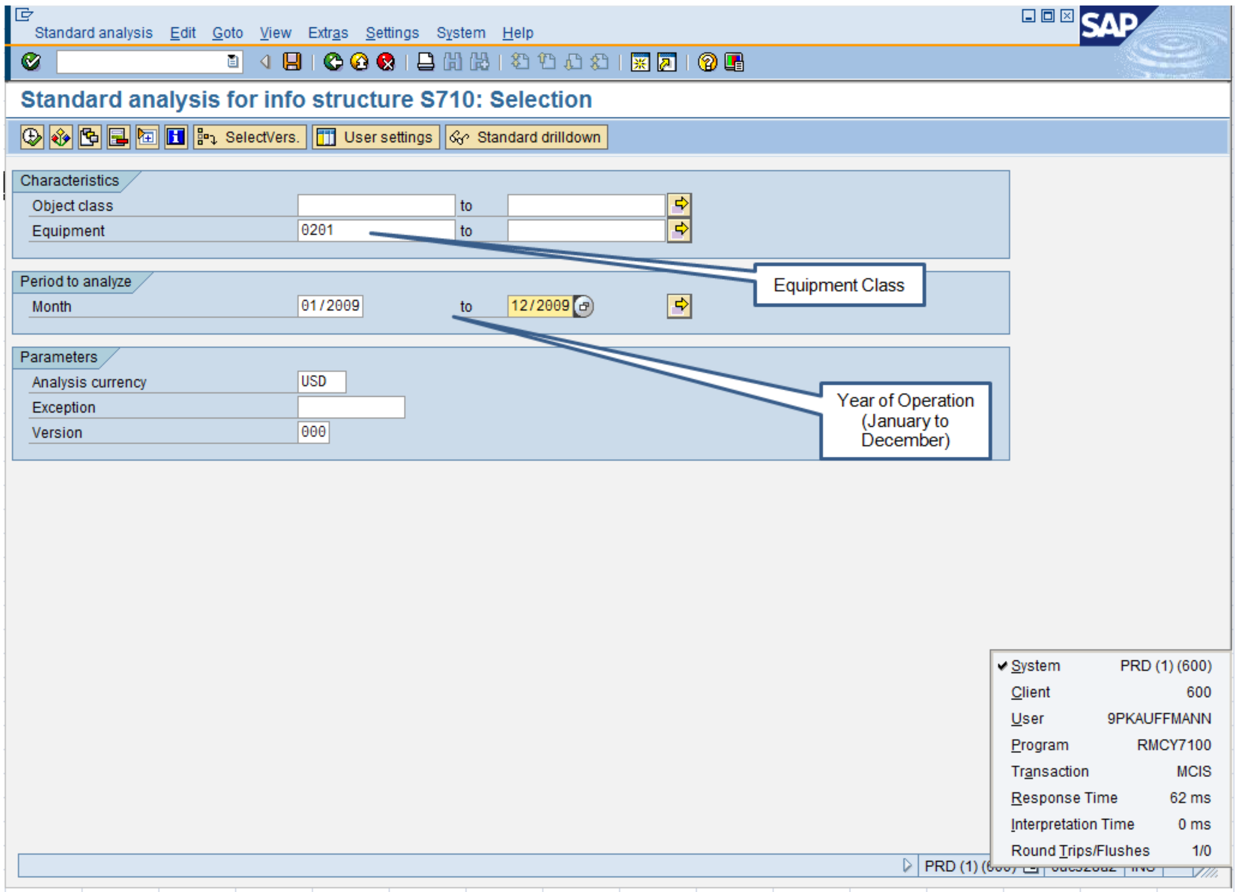
Appendix B SAP Screen Captures

SAP IH08 Equipment ID




Program Edit Goto System Help
Display Equipment: Equipment Select
Division (01 to 14) followed by "10"
Stock batch to
Configurable material to
Reference configuration
Location data
Maintenance plant 0110 to
Location to
Room to
Plant section to
Work center to
ABC indicator to
Sort field to
Company Code to
Controlling Area to
Business Area to
Asset to
Subnumber to
Cost Center to
WBS Element to
Standing order to
Settlement order to
Maintenance data
Functional location to
Superord. Equipment to
Position to
Technical IdentNo. to
System PRD (1) (600)
Client 600
User 9PKAUFFMANN
Program RIEQUI20
Transaction IH08
Response Time 343 ms
Interpretation Time 78 ms
Round Trips/Flushes 5/2

SAP MCIS S710 Maintenance Data

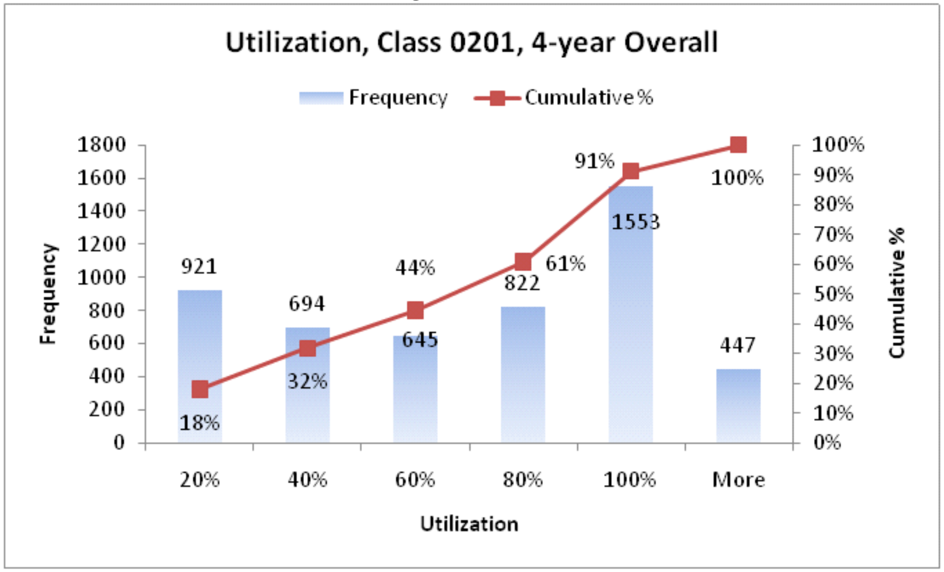


Appendix C Utilization Figures

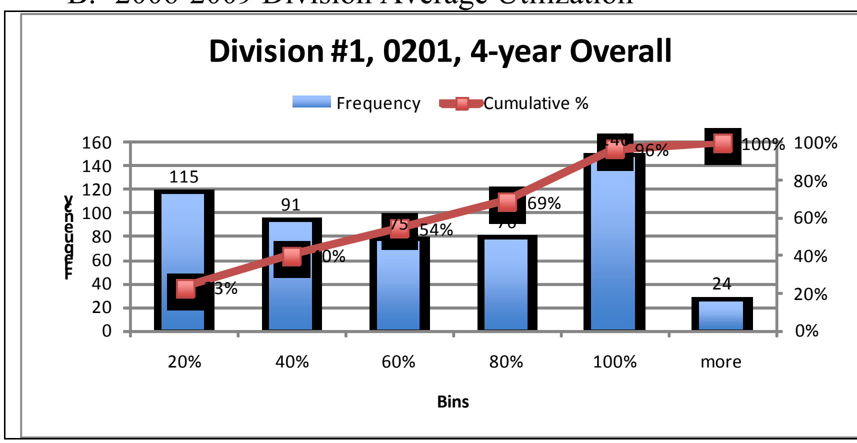
This appendix contains a comprehensive set of utilization charts for the six equipment classes in this study. The histograms show the four year utilization levels for the classes by region and overall.

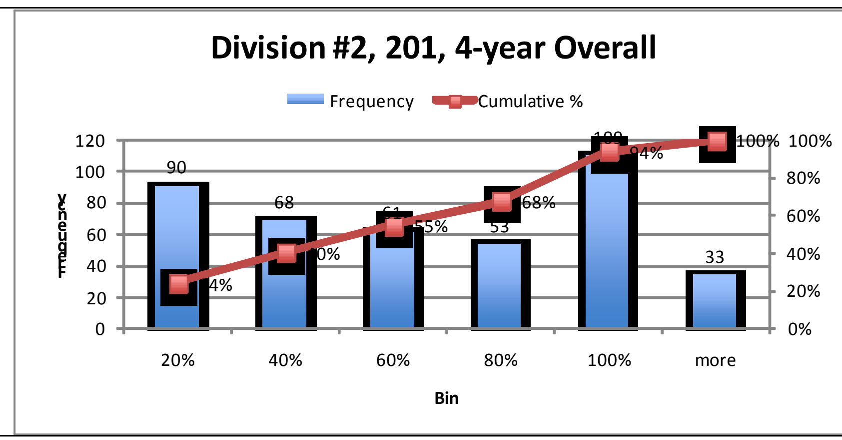
Utilization by Division– Class 201, Pickup trucks

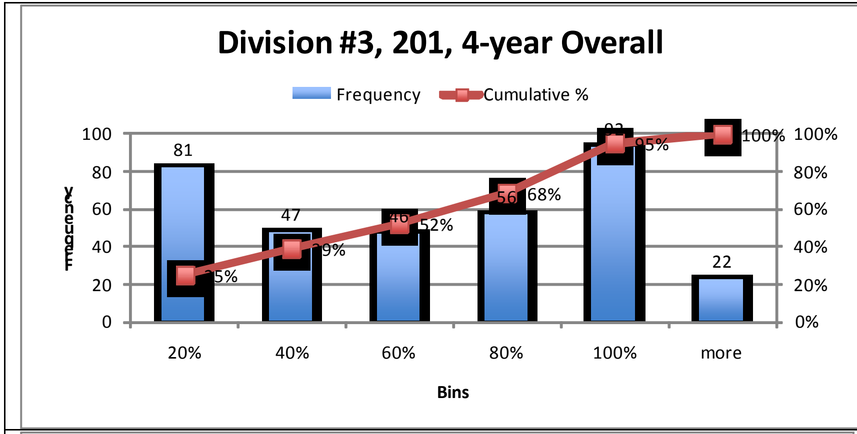
A. 2006-2009 Statewide Average Utilization

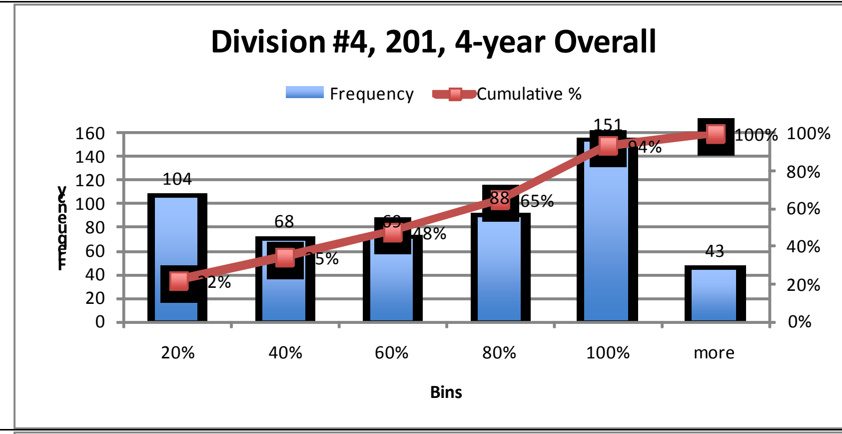


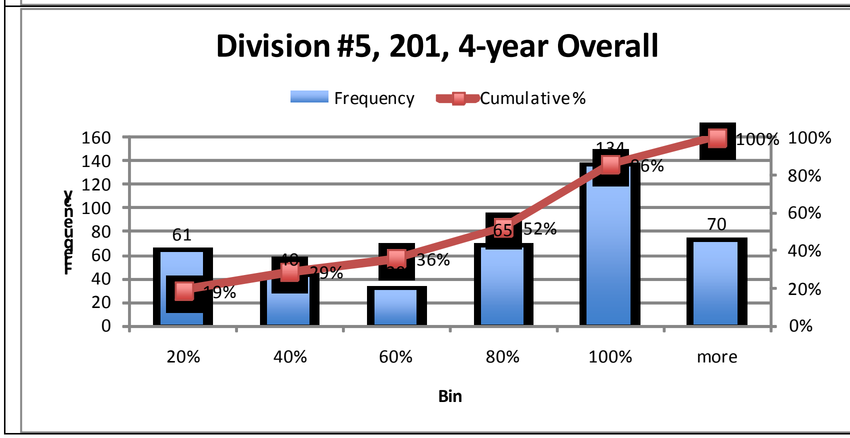
B. 2006-2009 Division Average Utilization

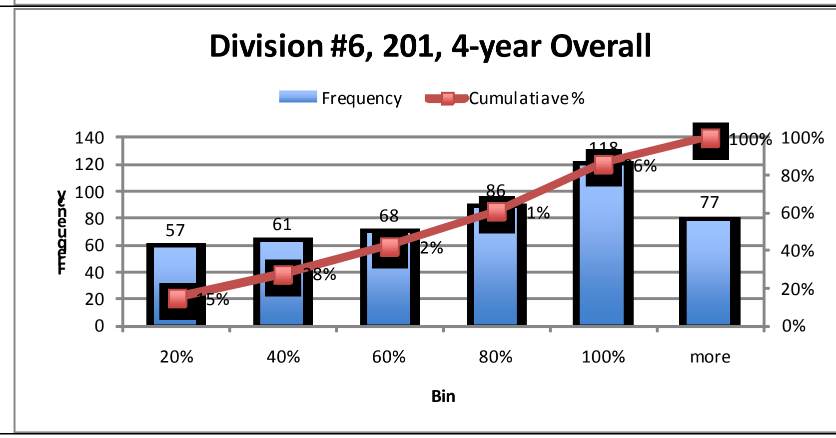


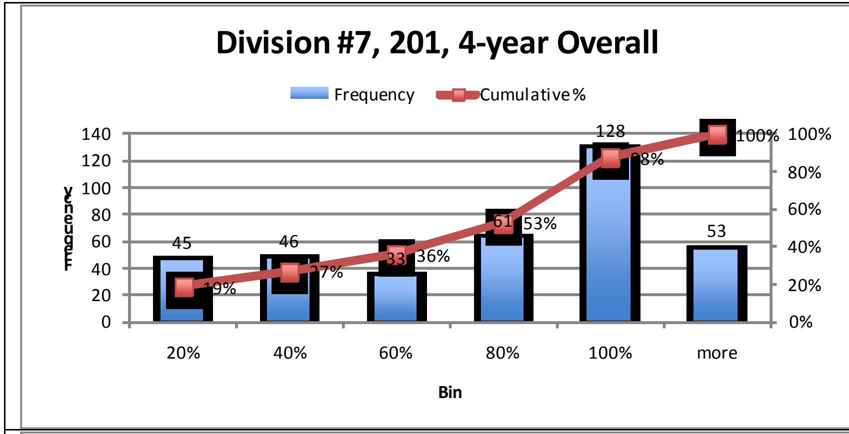



Division #3, 201, 4-year Overall
Frequency
Cumulative %
Bins

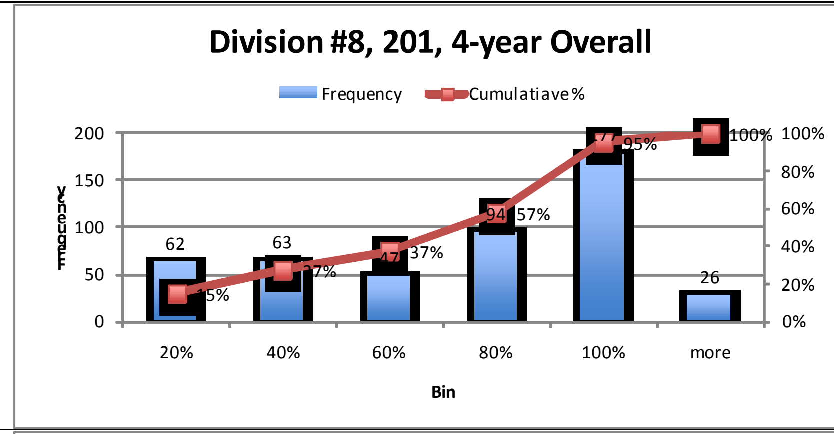

Division #4, 201, 4-year Overall
Frequency
Cumulative %
Bins


Division #5, 201, 4-year Overall
Frequency
Cumulative %
Bin

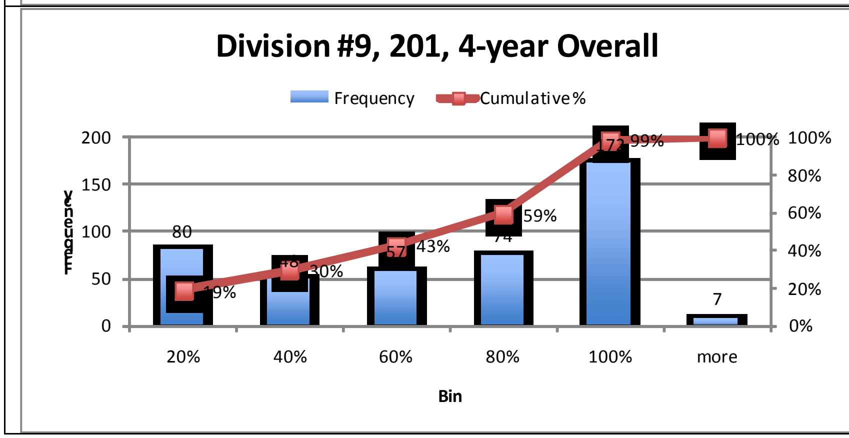

Division #6, 201, 4-year Overall
Frequency
Cumulatiave %
Bin



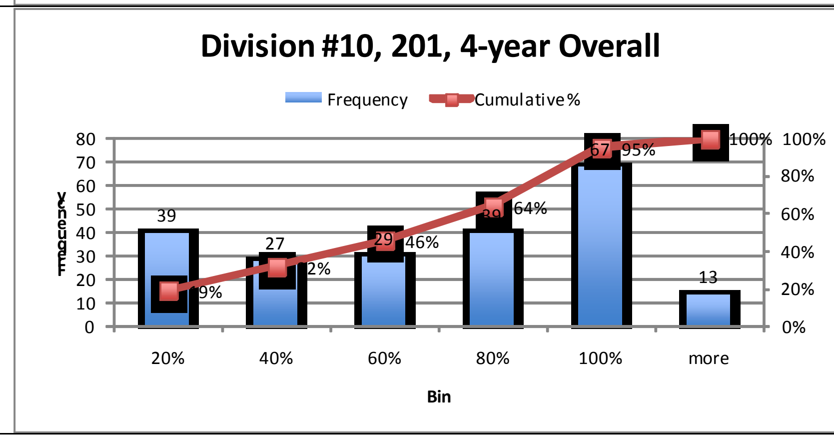
Division #7, 201, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more
45
46
128
53
36%
53%
100%



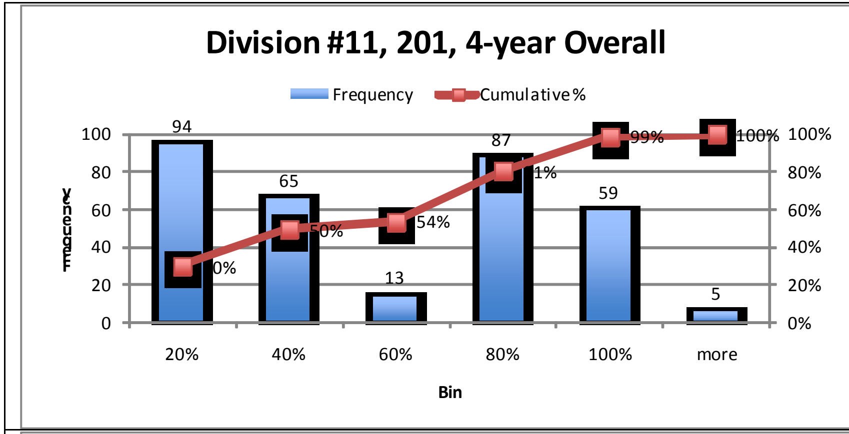
Division #8, 201, 4-year Overall
Frequency
Cumulatiave %
Bin
20%
40%
60%
80%
100%
more
62
63
26
37%
57%
95%
100%

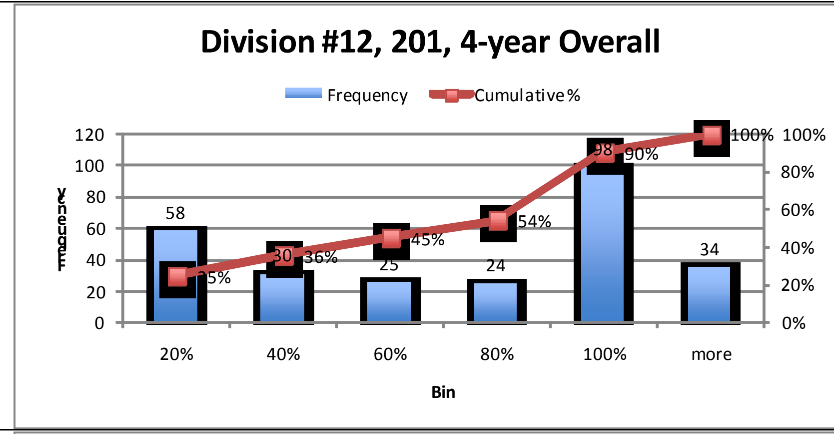


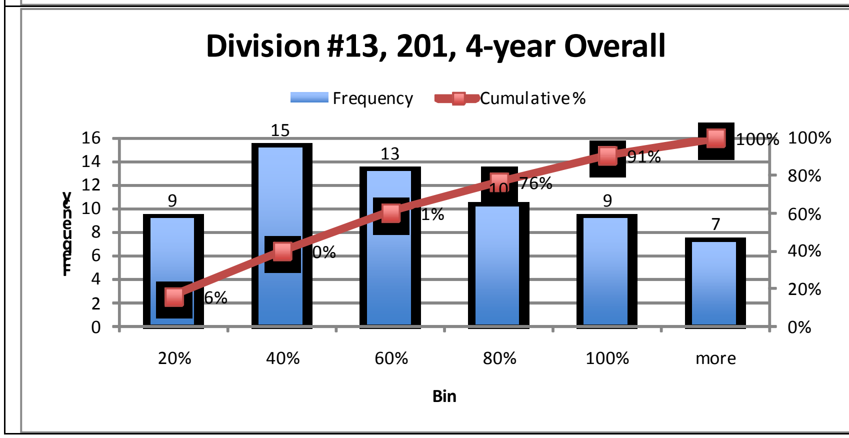
Division #9, 201, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more
80
7
30%
43%
59%
99%
100%

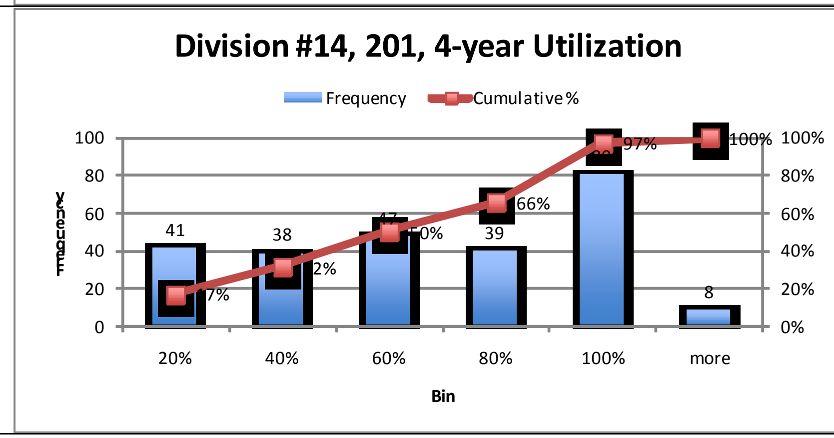


Division #10, 201, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more
39
27
13
46%
64%
95%
100%


Division #11, 201, 4-year Overall
Frequency
Cumulative %
100
80
60
40
20
0
100%
80%
60%
40%
20%
0%
94
65
13
87
59
5
54%
99%
100%
20%
40%
60%
80%
100%
more
Bin

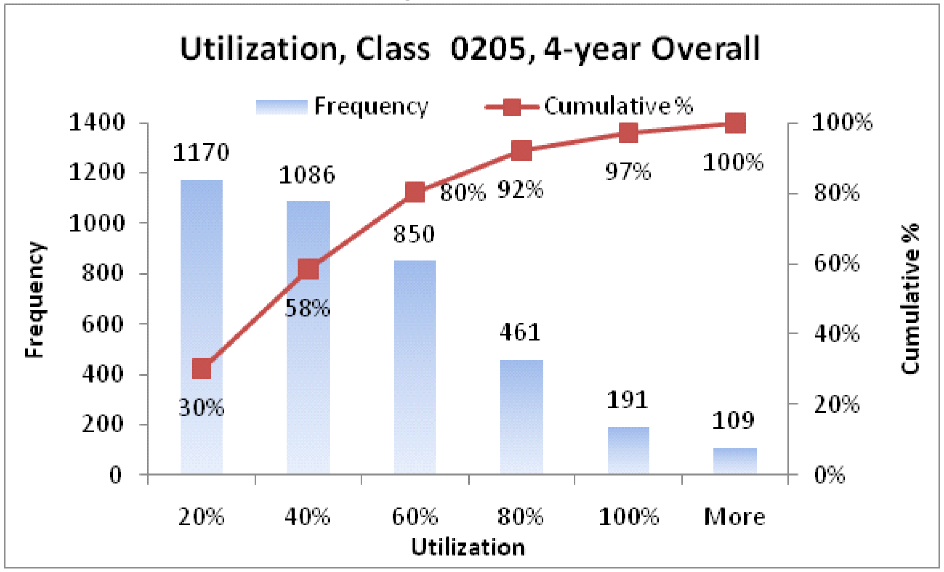

Division #12, 201, 4-year Overall
Frequency
Cumulative %
120
100
80
60
40
20
0
100%
80%
60%
40%
20%
0%
58
30
25
24
98
34
36%
45%
54%
90%
100%
20%
40%
60%
80%
100%
more
Bin


Division #13, 201, 4-year Overall
Frequency
Cumulative %
16
14
12
10
8
6
4
2
0
100%
80%
60%
40%
20%
0%
9
15
13
10
9
7
76%
91%
100%
20%
40%
60%
80%
100%
more
Bin

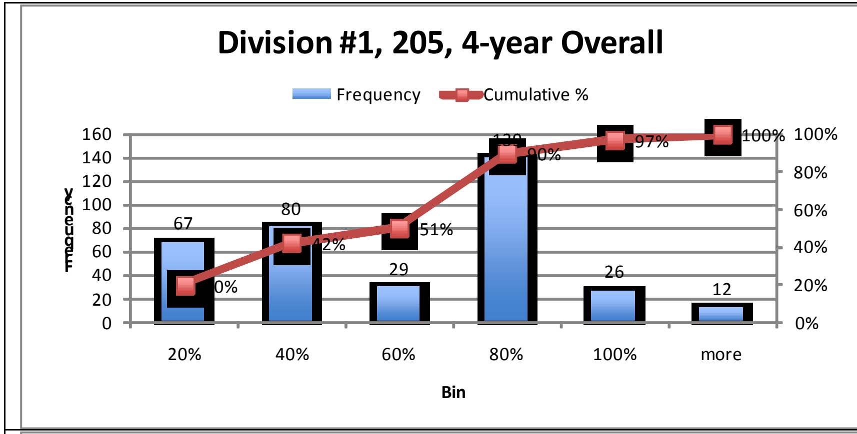

Division #14, 201, 4-year Utilization
Frequency
Cumulative %
100
80
60
40
20
0
100%
80%
60%
40%
20%
0%
41
38
47
39
8
66%
97%
100%
20%
40%
60%
80%
100%
more
Bin

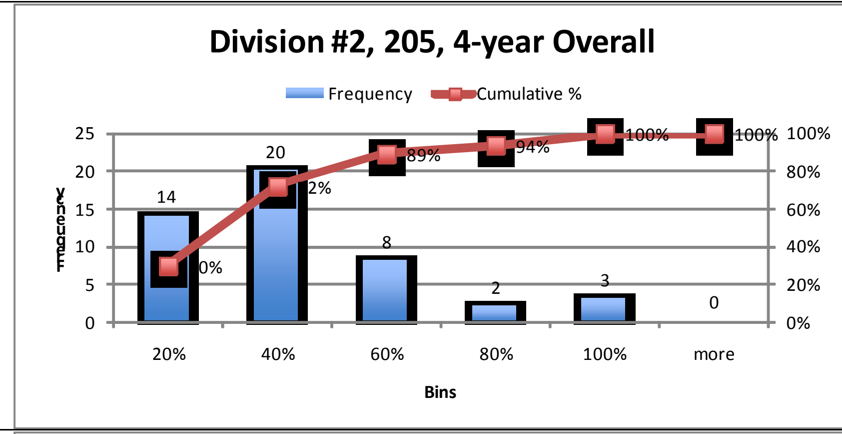
Utilization by Division- Class 0205, Single Axle Dump Trucks

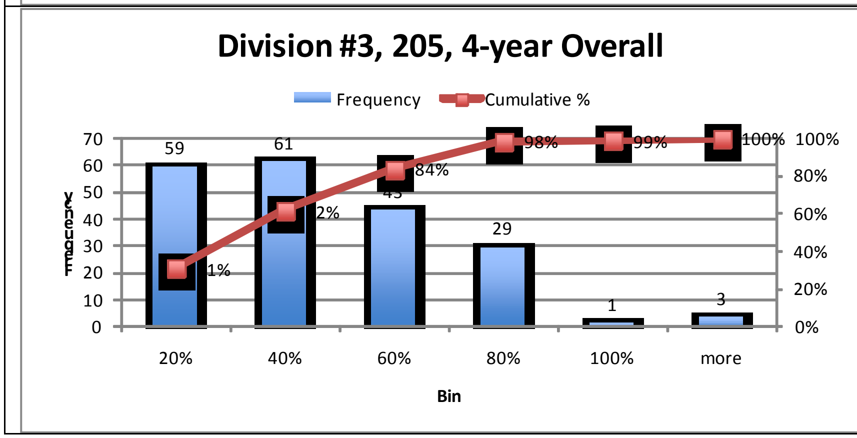
A. 2006-2009 Statewide Average Utilization

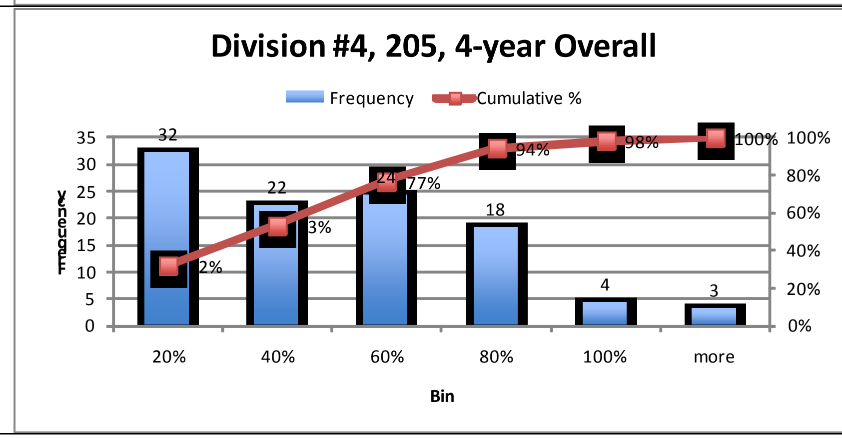


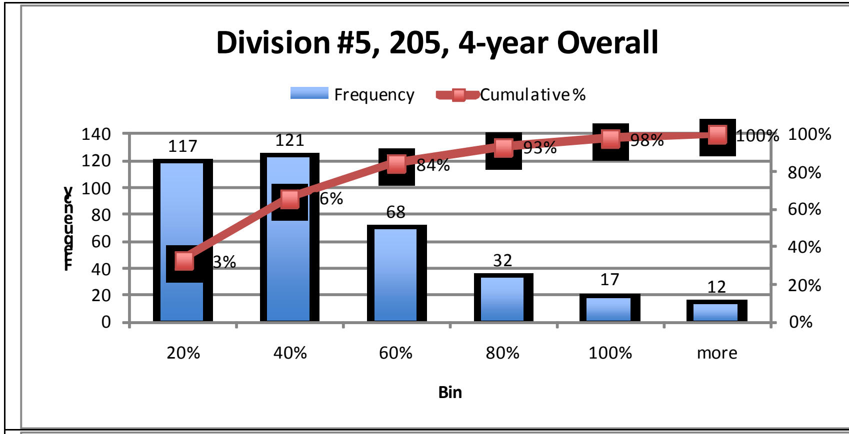
B. 2006-2009 Division Average Utilization

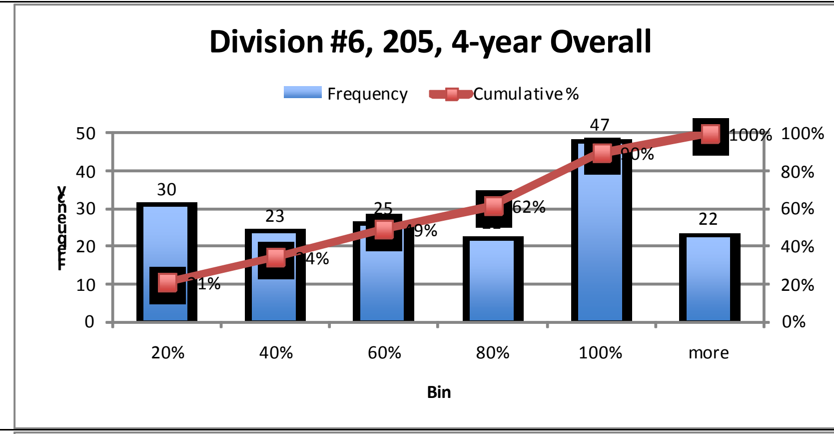

Division #1, 205, 4-year Overall
Frequency
Cumulative %
67
80
29
139
26
12
20%
40%
60%
80%
100%
more
Bin

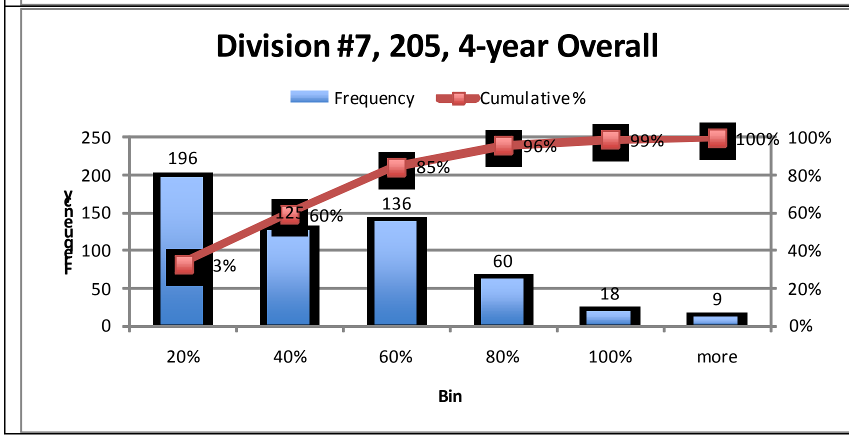

Division #2, 205, 4-year Overall
Frequency
Cumulative %
14
20
8
2
3
0
89%
94%
100%
100%
20%
40%
60%
80%
100%
more
Bins

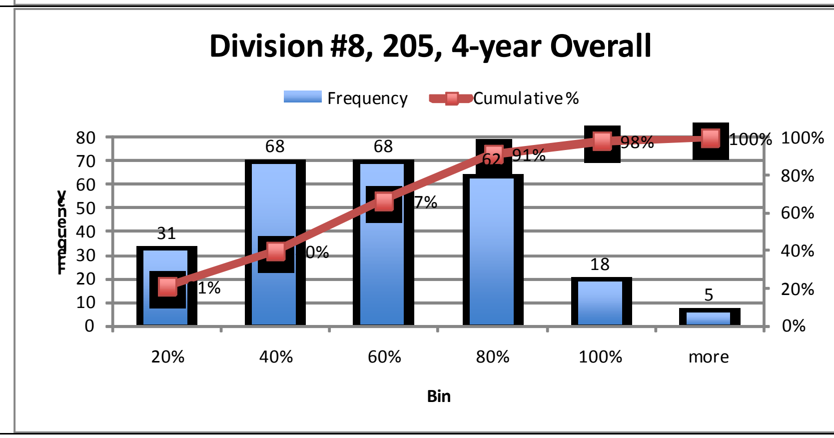

Division #3, 205, 4-year Overall
Frequency
Cumulative %
59
61
29
1
3
84%
98%
99%
100%
20%
40%
60%
80%
100%
more
Bin

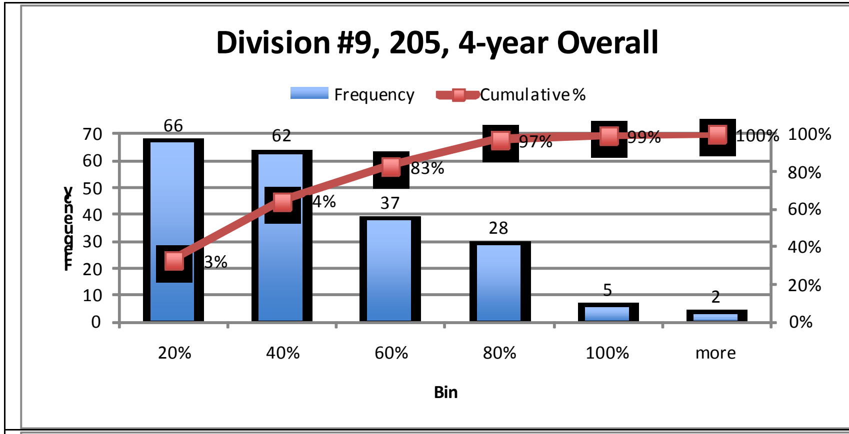

Division #4, 205, 4-year Overall
Frequency
Cumulative %
32
22
24
77%
18
4
3
94%
98%
100%
20%
40%
60%
80%
100%
more
Bin


Division #5, 205, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
117
121
68
32
17
12
93%
84%
98%
100%

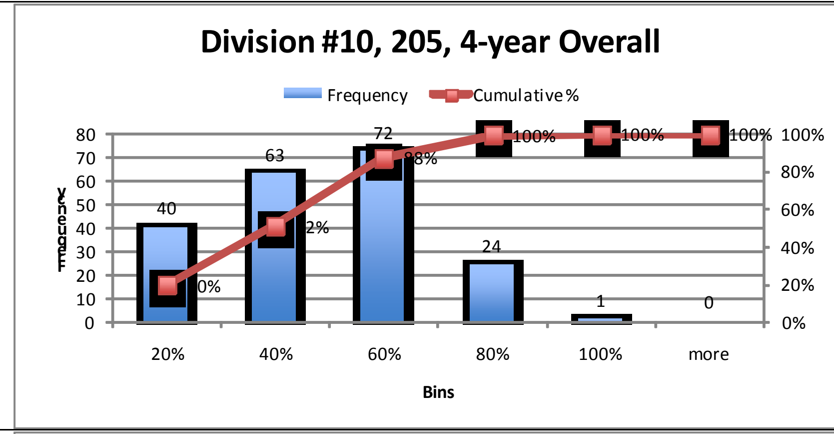

Division #6, 205, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
30
23
25
47
22
62%
100%


Division #7, 205, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
196
125
136
60
18
9
60%
85%
96%
99%
100%

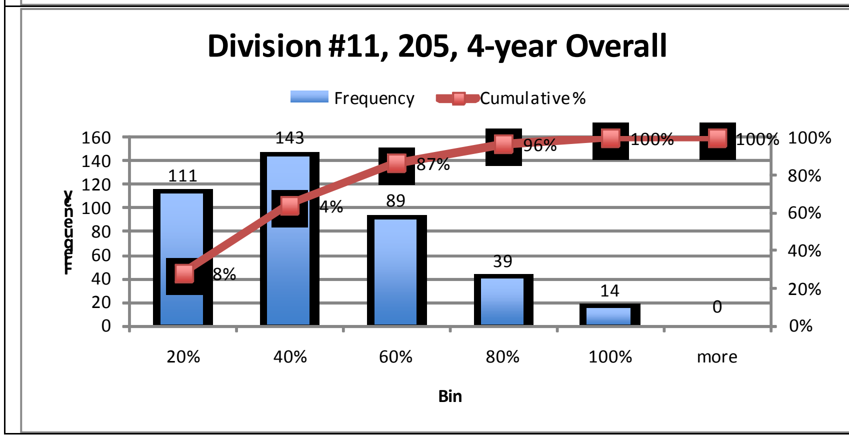

Division #8, 205, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
31
68
68
62
18
5
91%
98%
100%



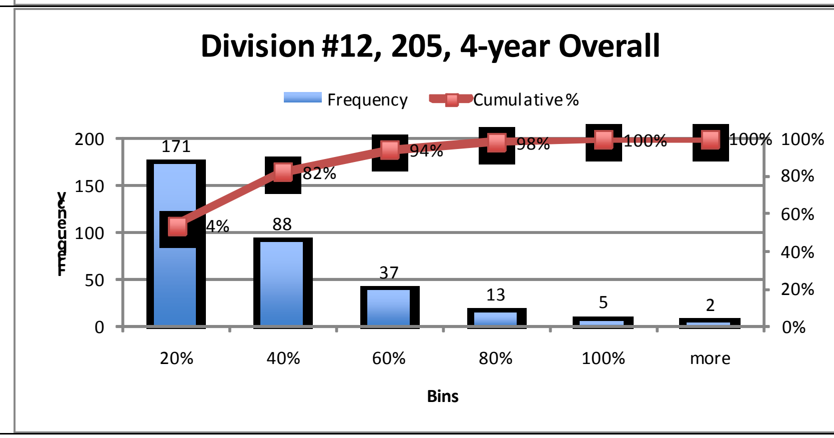
Division #9, 205, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
66
62
37
28
5
2
97%
99%
100%
83%
0
10
20
30
40
50
60
70
0%
20%
40%
60%
80%
100%



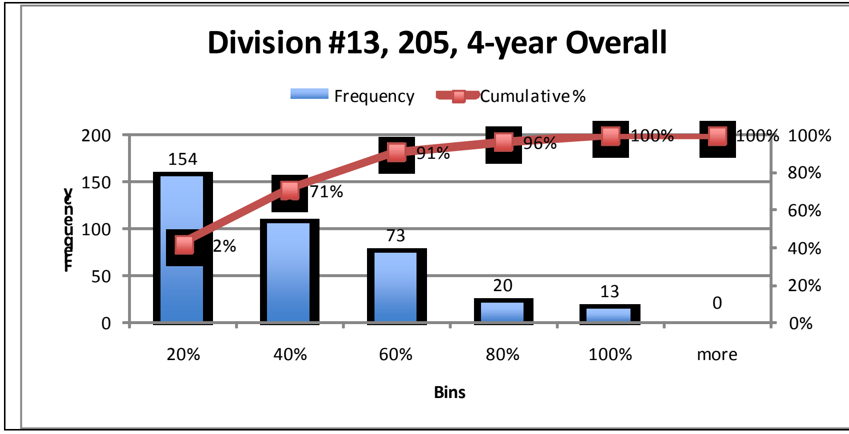
Division #10, 205, 4-year Overall
Frequency
Cumulative %
Frequency
Bins
20%
40%
60%
80%
100%
more
40
63
72
24
1
0
100%
100%
100%
0
10
20
30
40
50
60
70
80
0%
20%
40%
60%
80%
100%

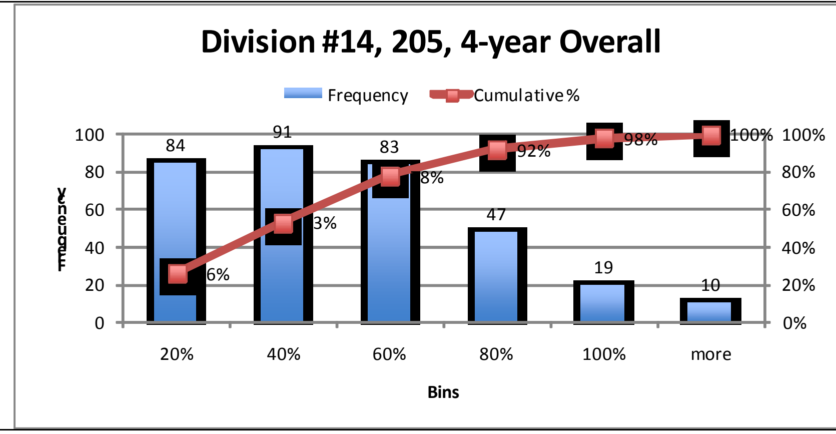


Division #11, 205, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
111
143
89
39
14
0
87%
96%
100%
100%
0
20
40
60
80
100
120
140
160
0%
20%
40%
60%
80%
100%



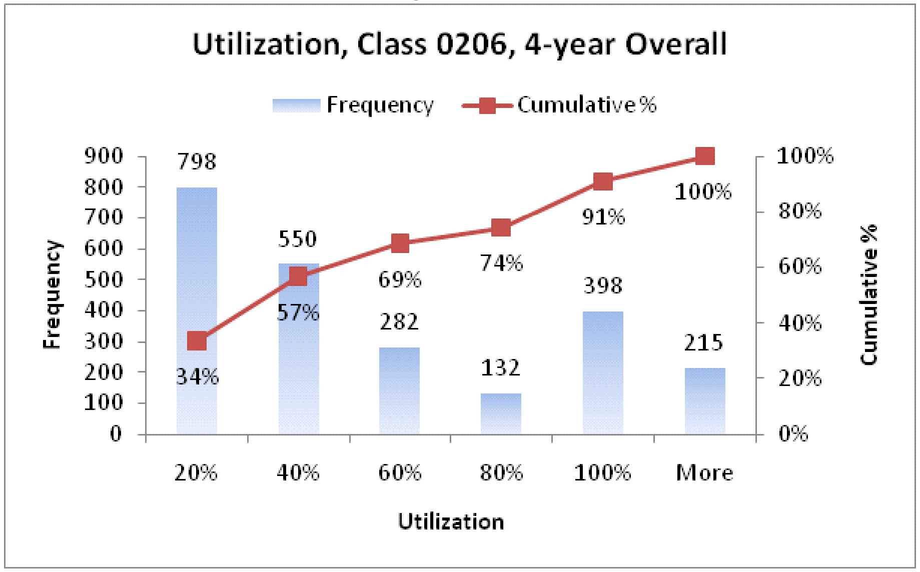
Division #12, 205, 4-year Overall
Frequency
Cumulative %
Frequency
Bins
20%
40%
60%
80%
100%
more
171
88
37
13
5
2
82%
94%
98%
100%
100%
0
50
100
150
200
0%
20%
40%
60%
80%
100%


Division #13, 205, 4-year Overall
Frequency
Cumulative %
154
73
20
13
0
71%
91%
96%
100%
100%
20%
40%
60%
80%
100%
more
Bins

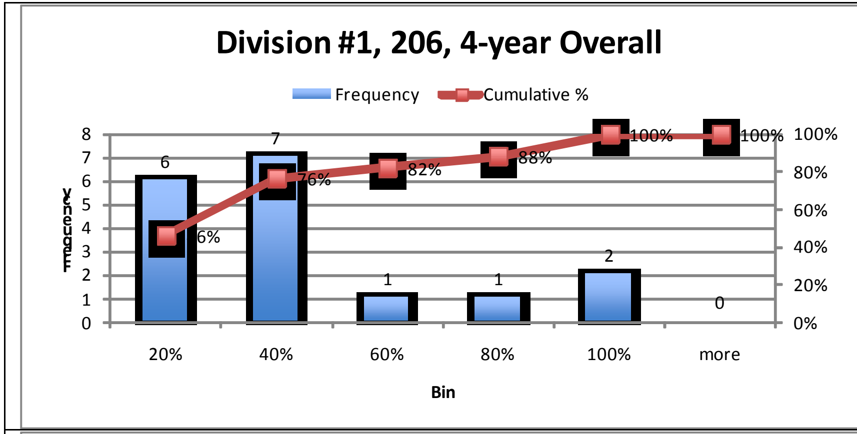

Division #14, 205, 4-year Overall
Frequency
Cumulative %
84
91
83
47
19
10
92%
98%
100%
20%
40%
60%
80%
100%
more
Bins

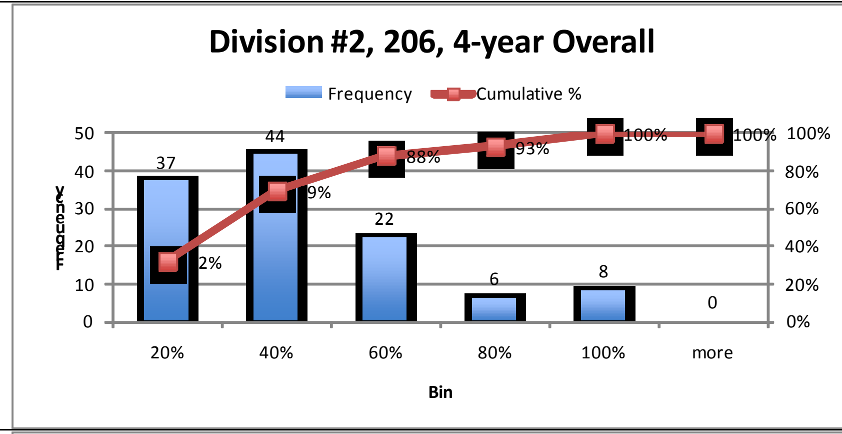
Utilization by Division- Class 0206 Flat Bed and Miscellaneous Trucks

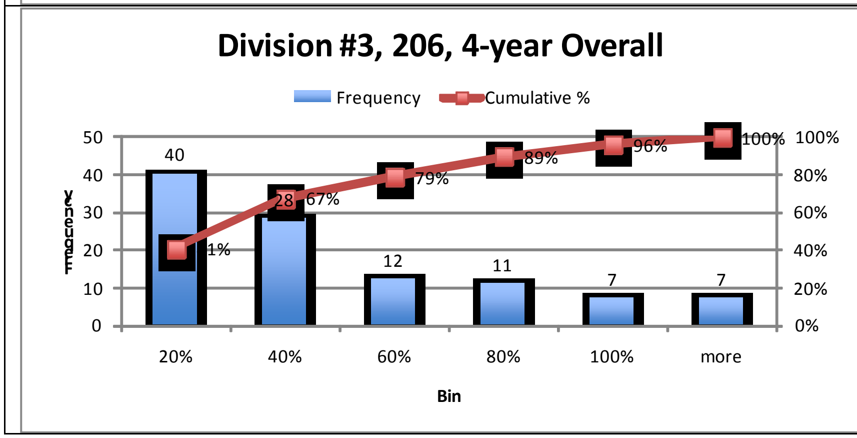
A. 2006-2009 Statewide Average Utilization

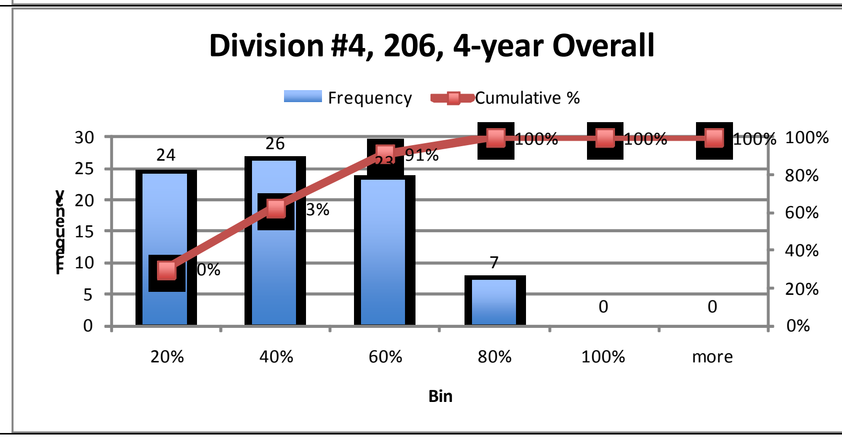


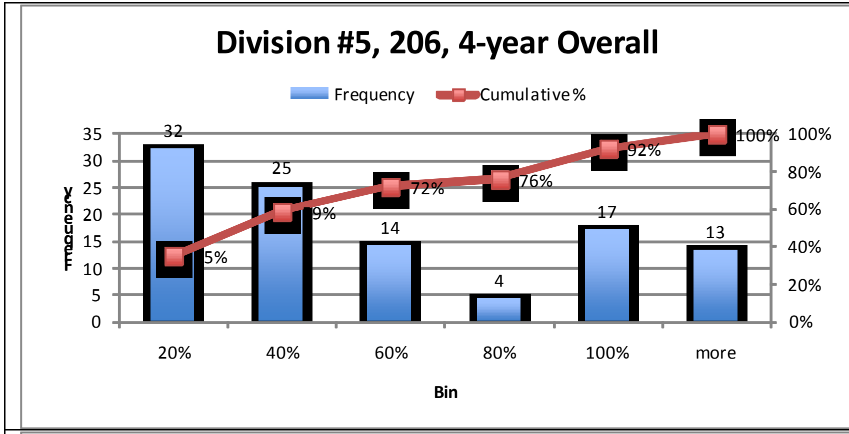
B. 2006-2009 Division Average Utilization

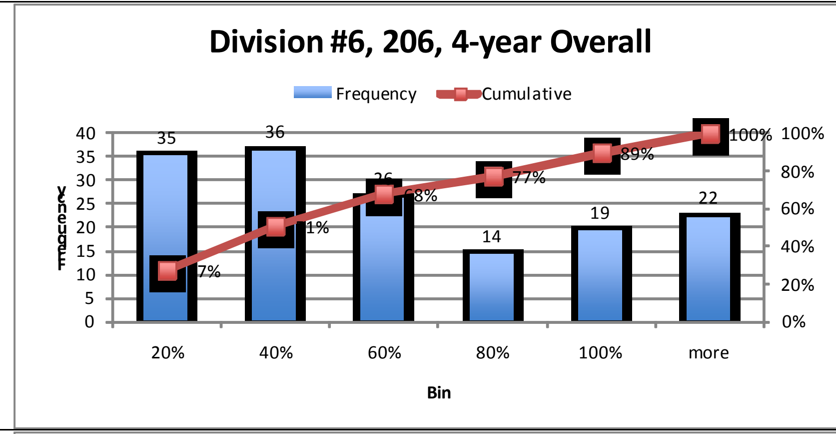

Division #1, 206, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
6
7
1
1
2
0
46%
76%
82%
88%
100%
100%

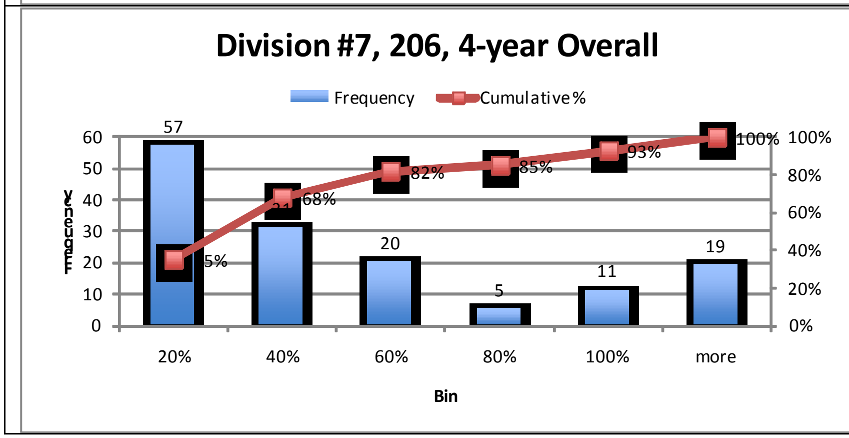

Division #2, 206, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
37
44
22
6
8
0
88%
93%
100%
100%

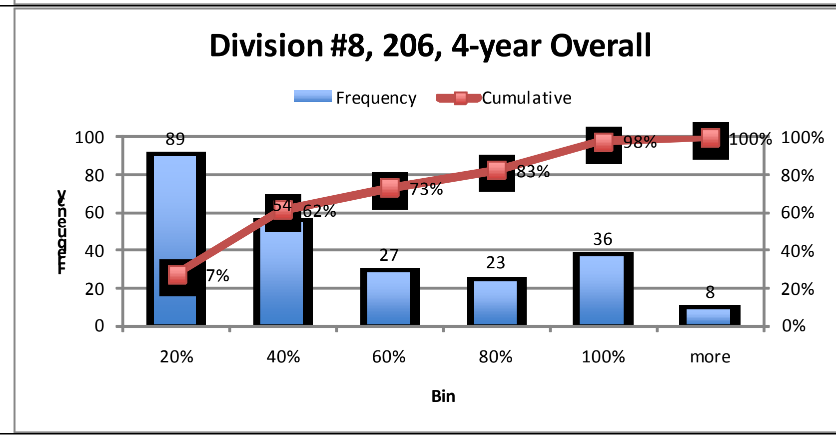

Division #3, 206, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
40
28
12
11
7
7
67%
79%
89%
96%
100%

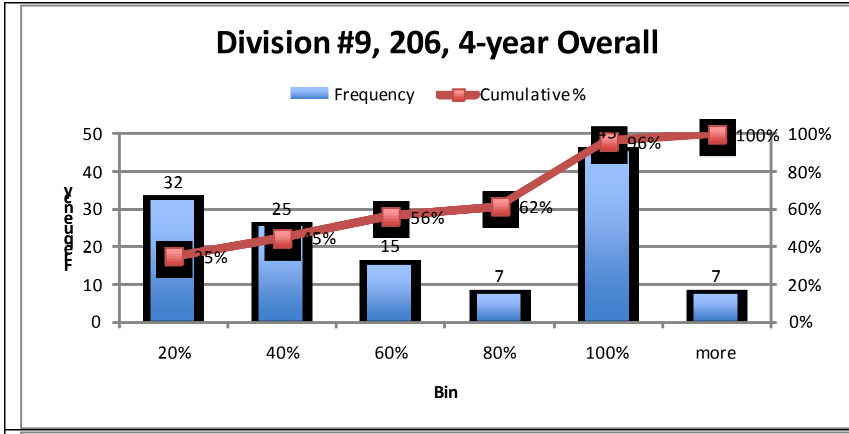

Division #4, 206, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
24
26
23
7
0
0
91%
100%
100%
100%

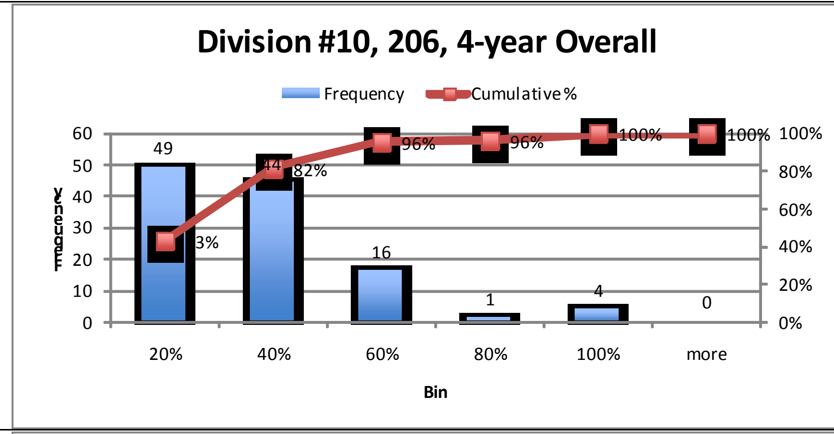

Division #5, 206, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more
32
25
14
4
17
13
72%
76%
92%
100%

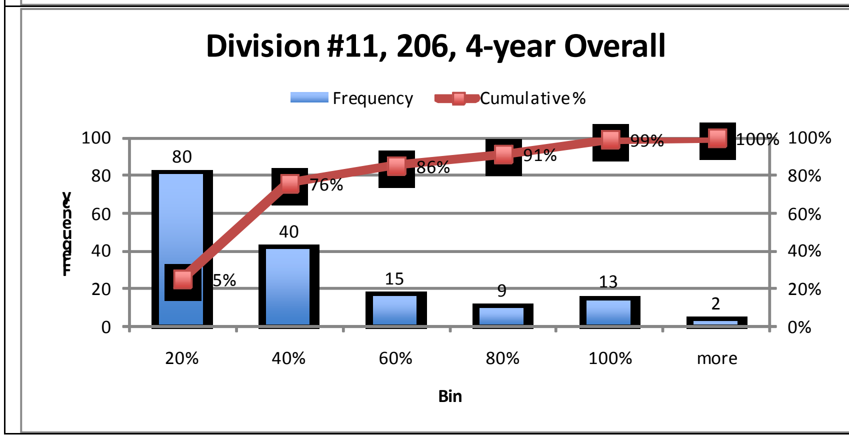

Division #6, 206, 4-year Overall
Frequency
Cumulative
Bin
20%
40%
60%
80%
100%
more
35
36
14
19
22
77%
89%
100%

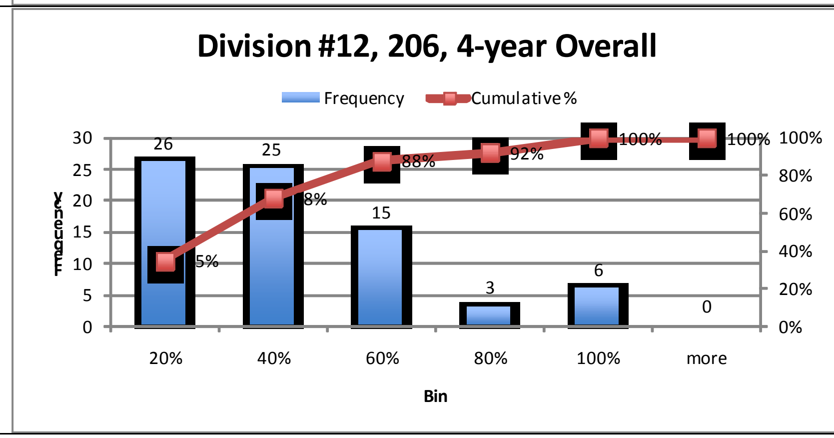

Division #7, 206, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more
57
20
5
11
19
68%
82%
85%
93%
100%

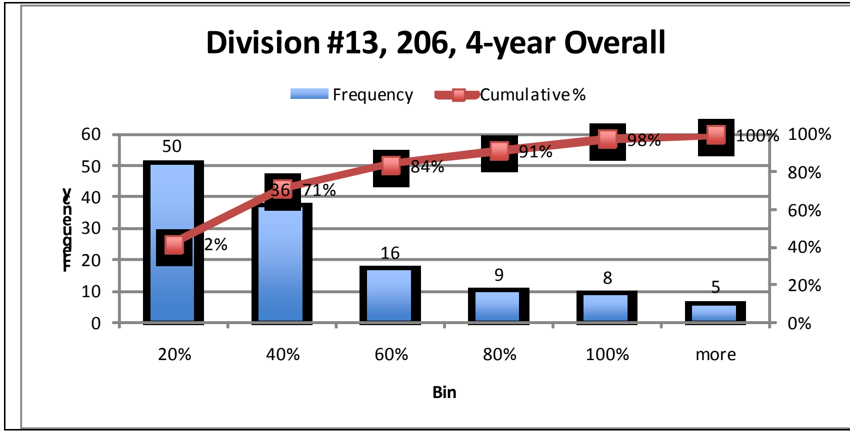

Division #8, 206, 4-year Overall
Frequency
Cumulative
Bin
20%
40%
60%
80%
100%
more
89
54
27
23
36
8
7%
62%
73%
83%
98%
100%

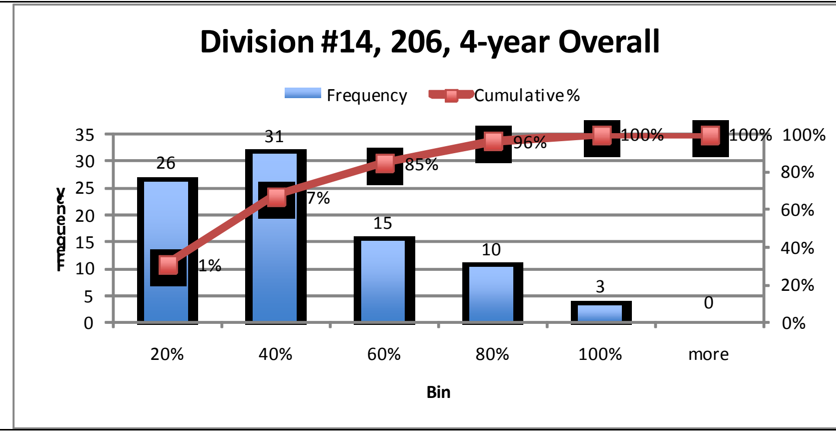

Division #9, 206, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more


Division #10, 206, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more


Division #11, 206, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more

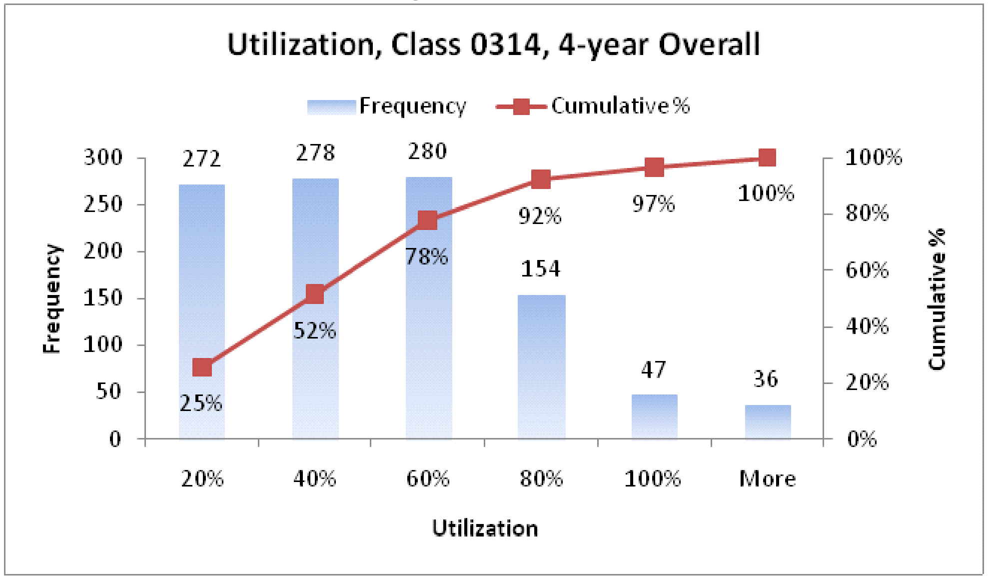

Division #12, 206, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more


Division #13, 206, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
50
36
16
9
8
5
2%
71%
84%
91%
98%
100%

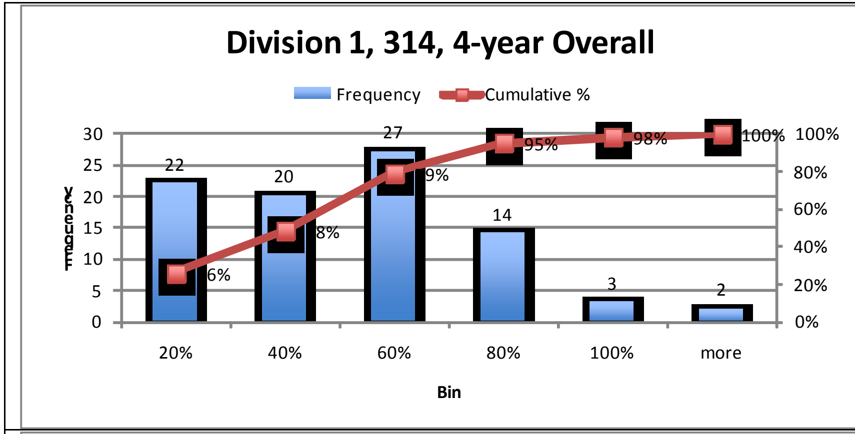

Division #14, 206, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
26
31
15
10
3
0
1%
7%
85%
96%
100%
100%

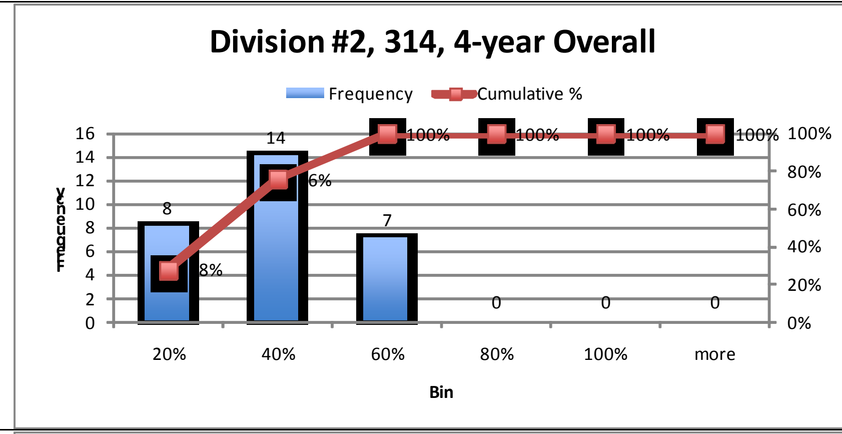
Utilization by Division- Class 0314 Loader-Backhoe

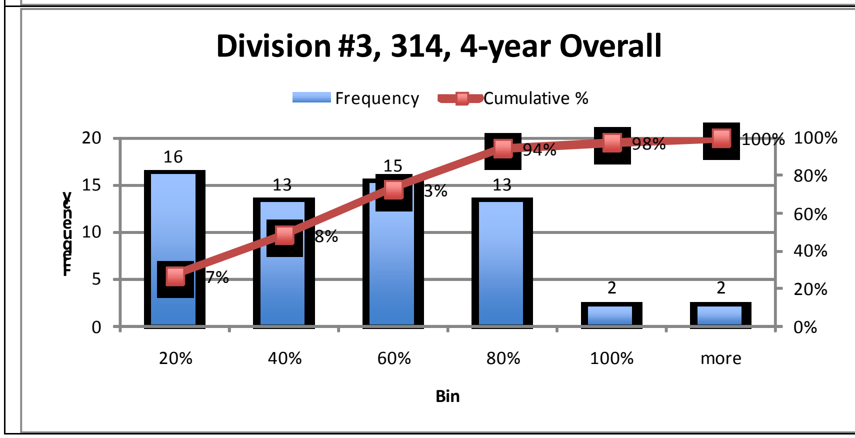
A. 2006-2009 Statewide Average Utilization

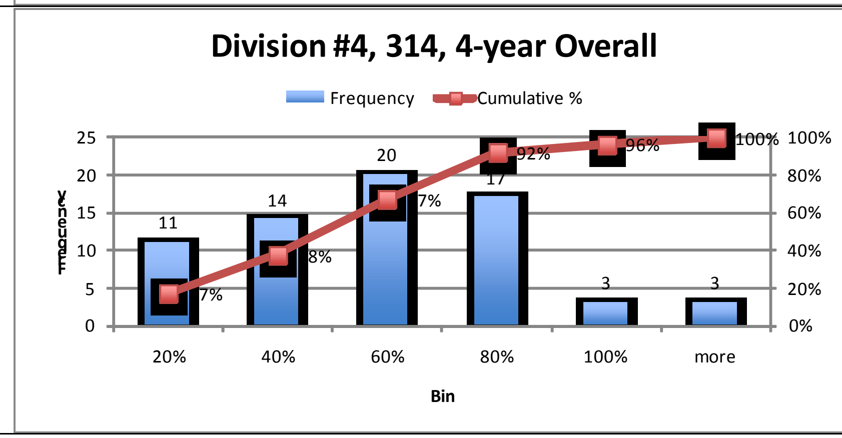


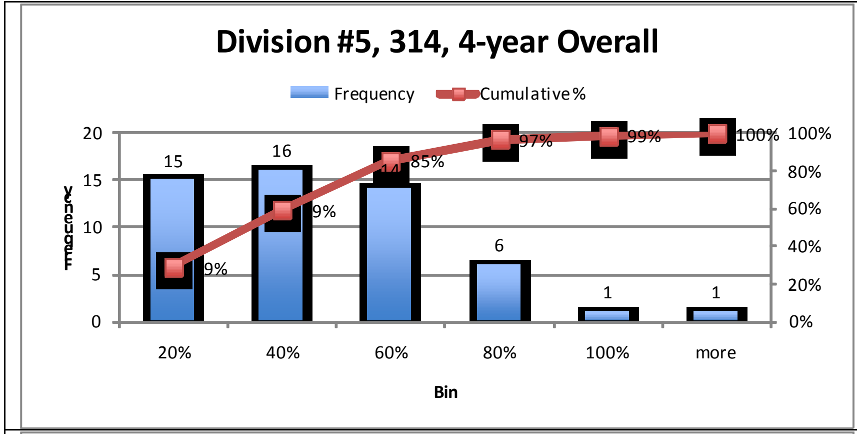
B. 2006-2009 Division Average Utilization

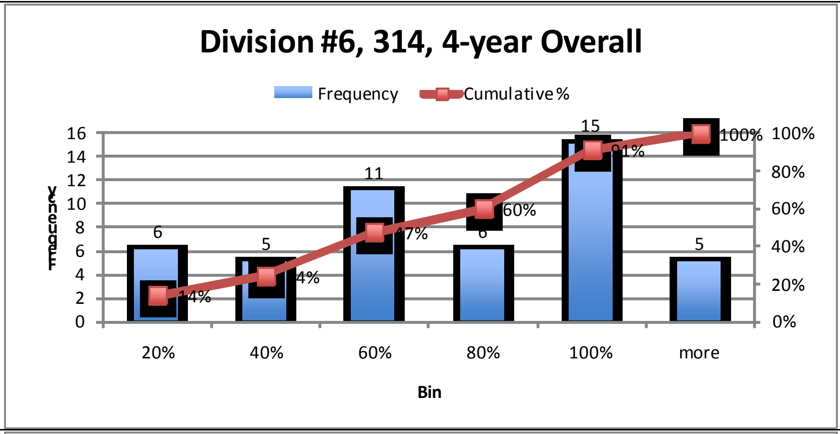

Division 1, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
22
20
27
14
3
2
6%
8%
9%
95%
98%
100%

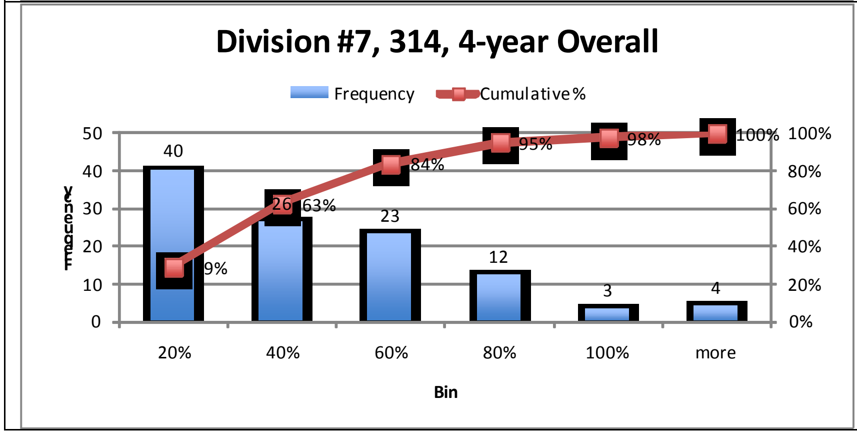

Division #2, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
8
14
7
0
0
0
8%
6%
100%
100%
100%
100%

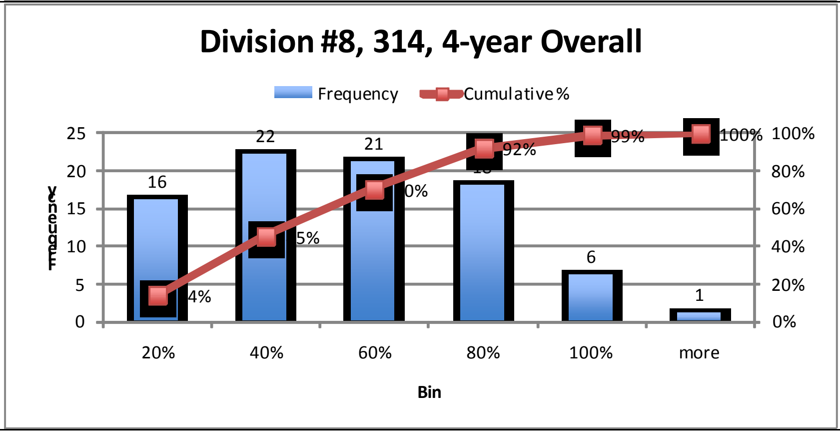

Division #3, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
16
13
15
13
2
2
7%
8%
3%
94%
98%
100%

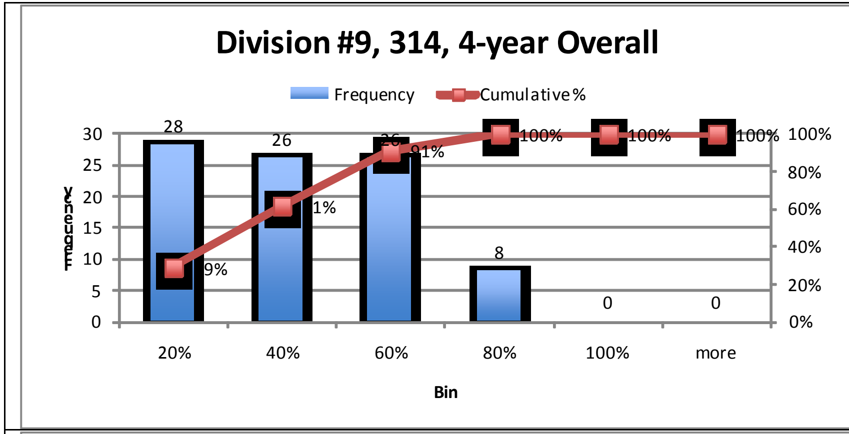

Division #4, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
11
14
20
17
3
3
7%
8%
7%
92%
96%
100%

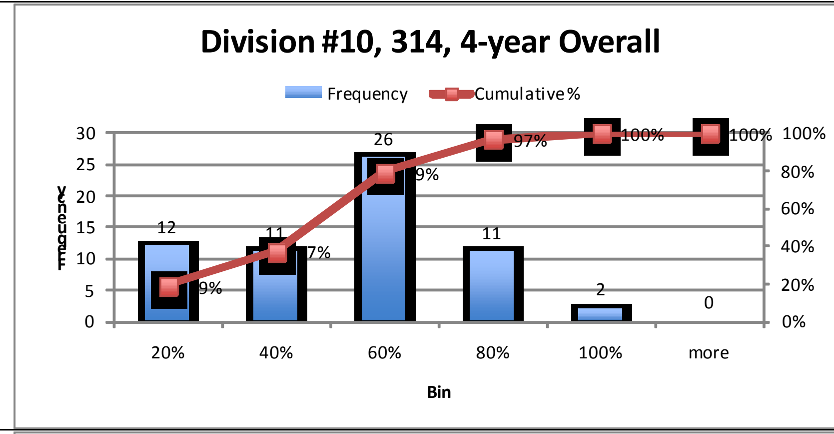

Division #5, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
15
16
6
1
1
85%
97%
99%
100%

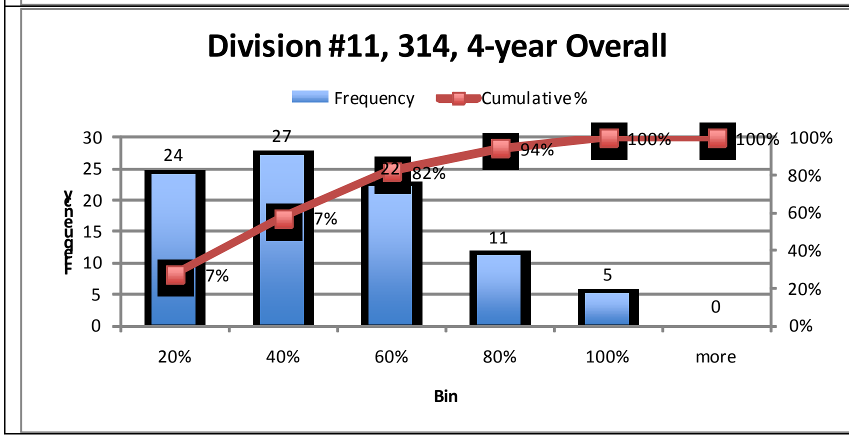

Division #6, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
6
5
11
15
5
60%
100%

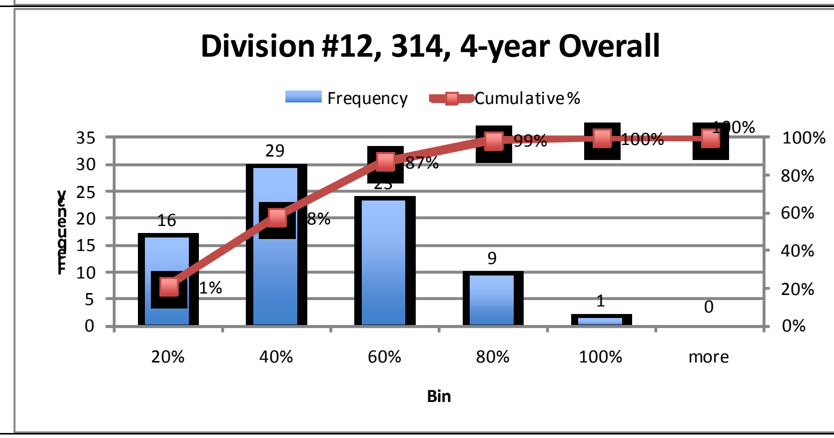

Division #7, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
40
26
23
12
3
4
63%
84%
95%
98%
100%

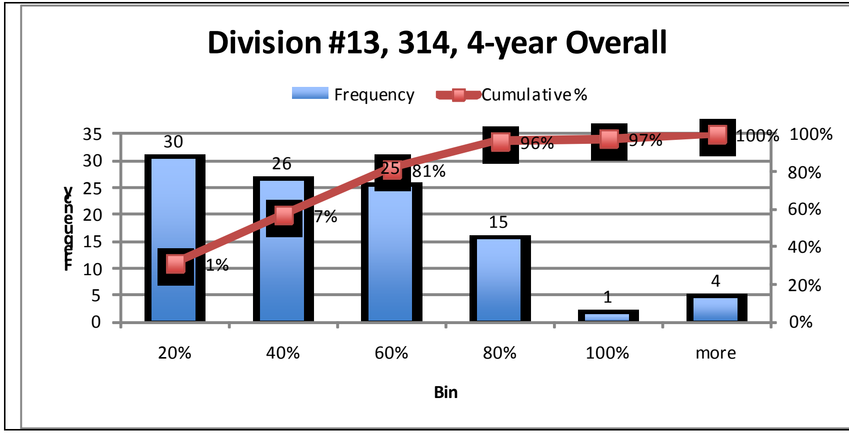

Division #8, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
16
22
21
6
1
92%
99%
100%

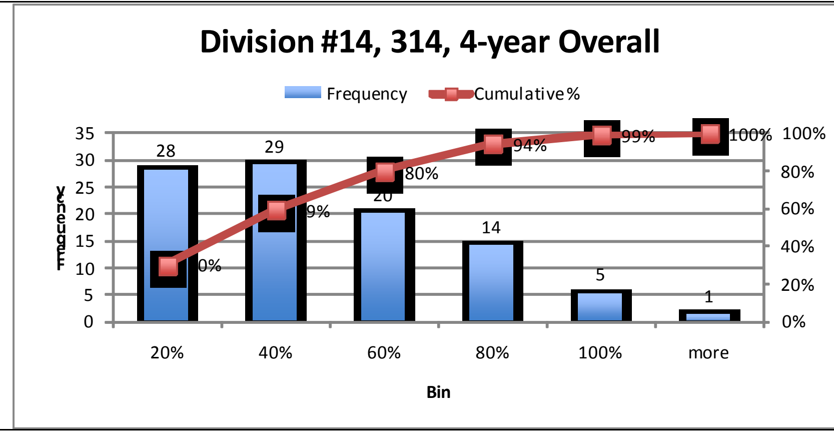

Division #9, 314, 4-year Overall
Frequency
Cumulative %
Bin
Frequency


Division #10, 314, 4-year Overall
Frequency
Cumulative %
Bin
Frequency


Division #11, 314, 4-year Overall
Frequency
Cumulative %
Bin
Frequency

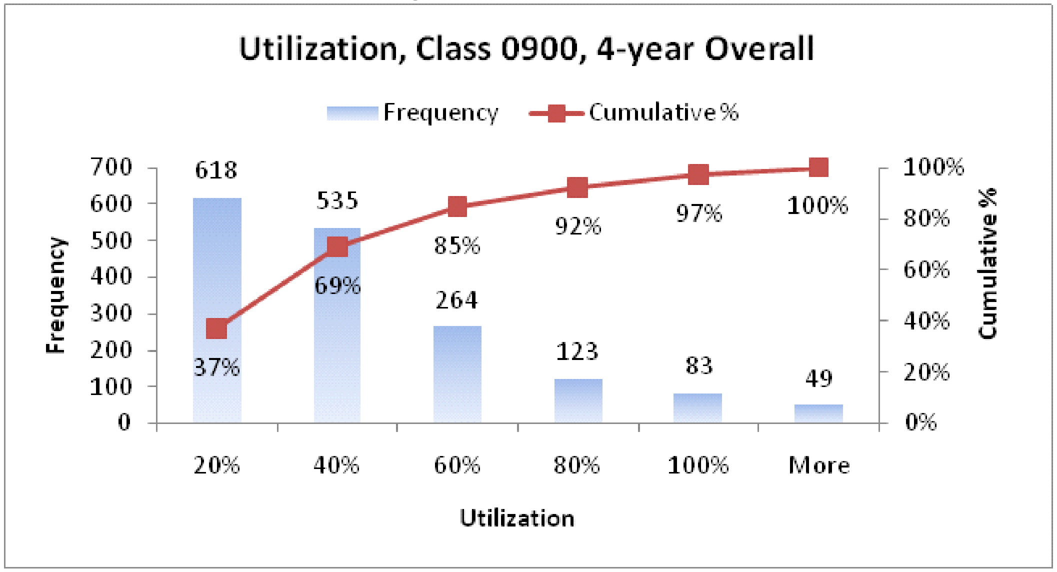

Division #12, 314, 4-year Overall
Frequency
Cumulative %
Bin
Frequency


Division #13, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
30
26
25
15
1
4
81%
96%
97%
100%

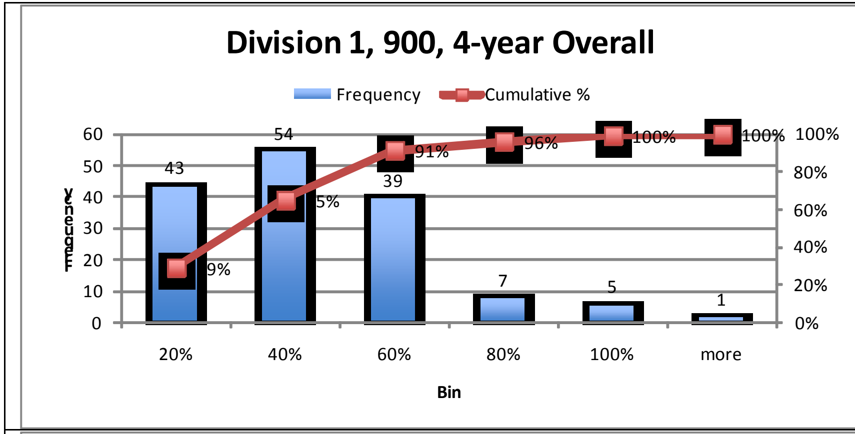

Division #14, 314, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
28
29
20
14
5
1
80%
94%
99%
100%

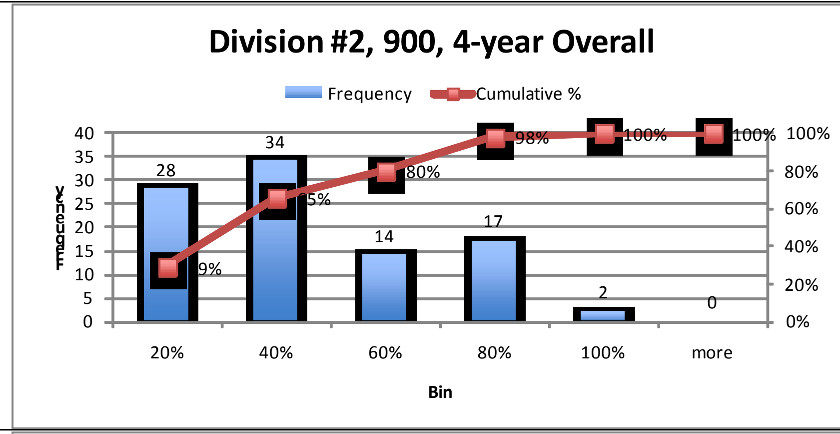
Utilization by Division- Class 0900 Motor Grader

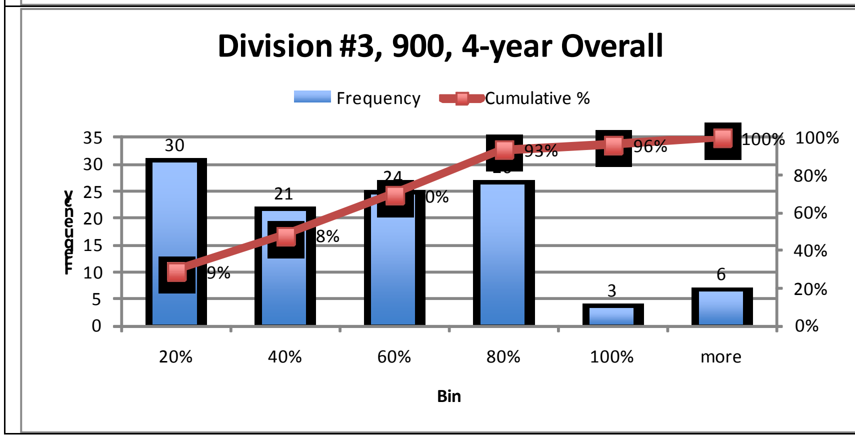
A. 2006-2009 Statewide Average Utilization

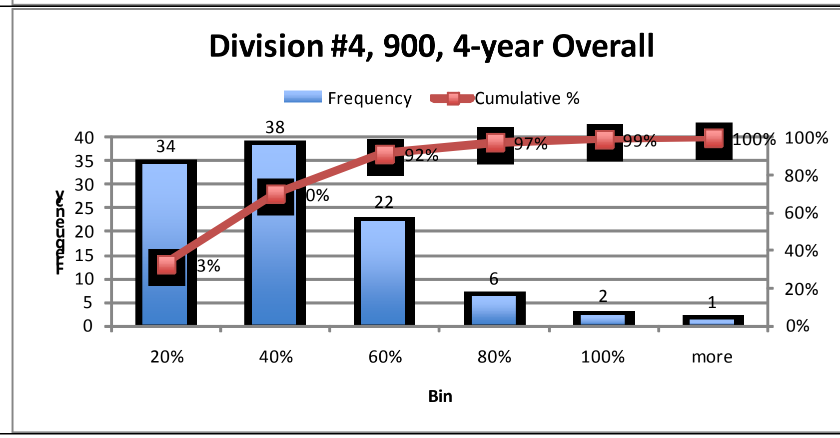


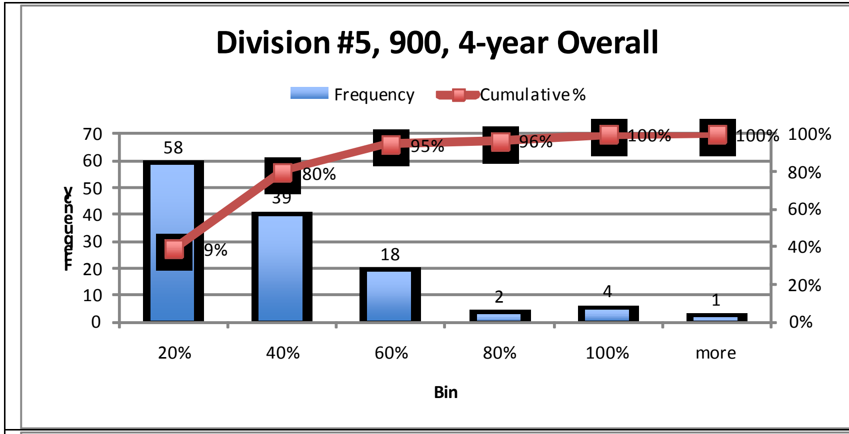
B. 2006-2009 Division Average Utilization

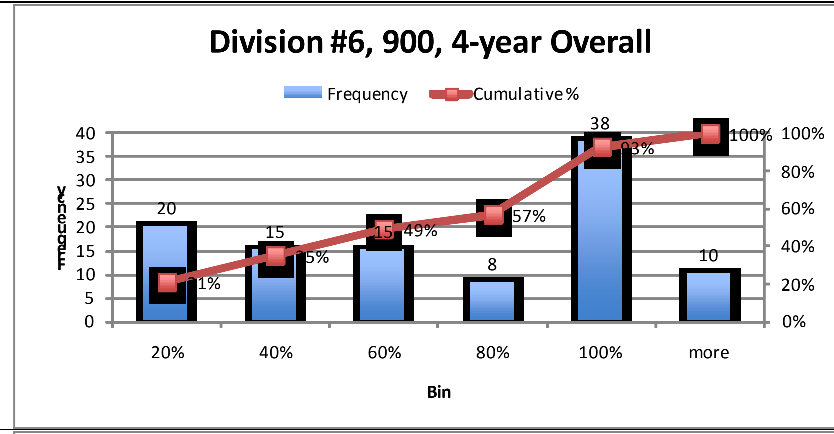

Division 1, 900, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more
43
54
39
7
5
1
91%
96%
100%
100%

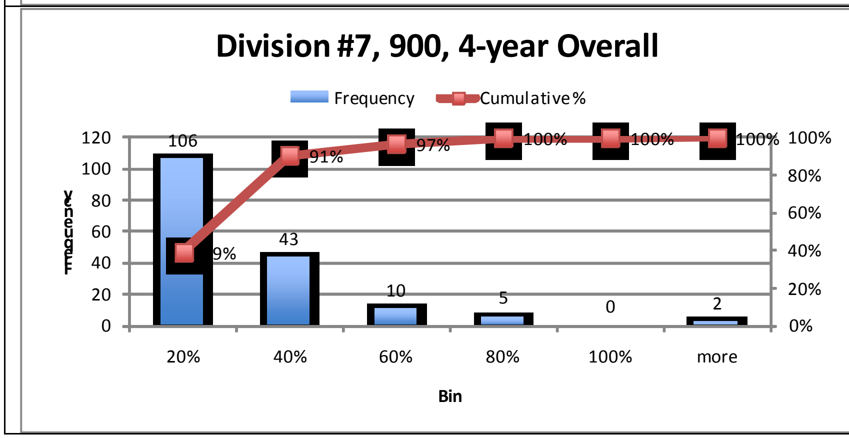

Division #2, 900, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more
28
34
14
17
2
0
80%
98%
100%
100%

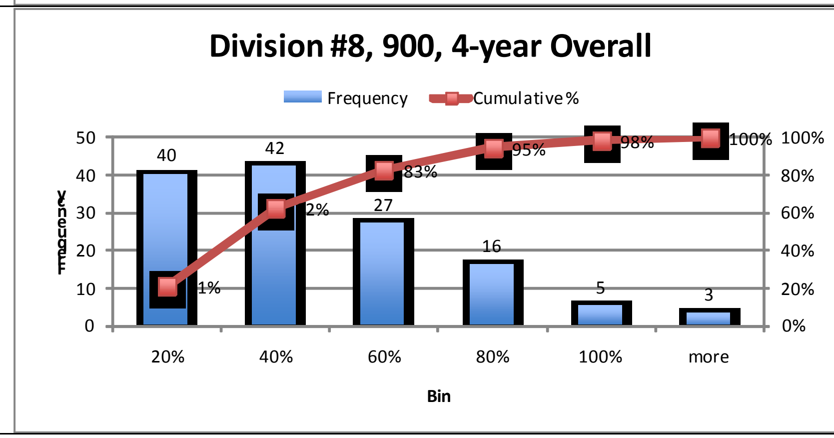

Division #3, 900, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more
30
21
3
6
93%
96%
100%

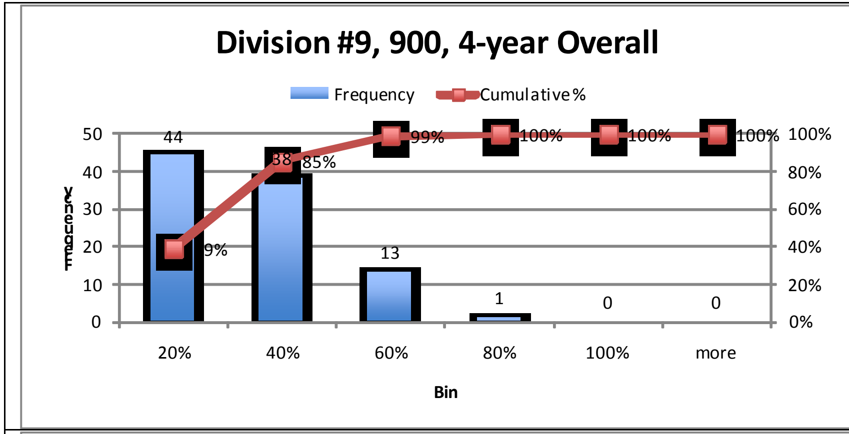

Division #4, 900, 4-year Overall
Frequency
Cumulative %
Bin
20%
40%
60%
80%
100%
more
34
38
22
6
2
1
92%
97%
99%
100%

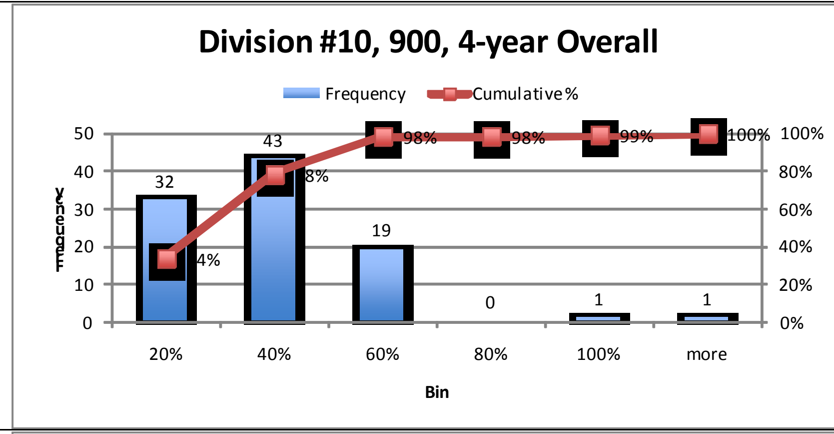

Division #5, 900, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
58
39
18
2
4
1
80%
95%
96%
100%
100%

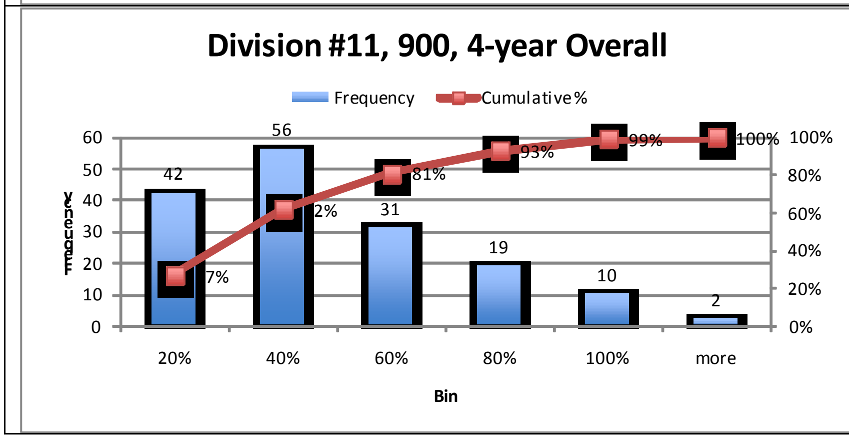

Division #6, 900, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
20
15
15
8
38
10
49%
57%
100%

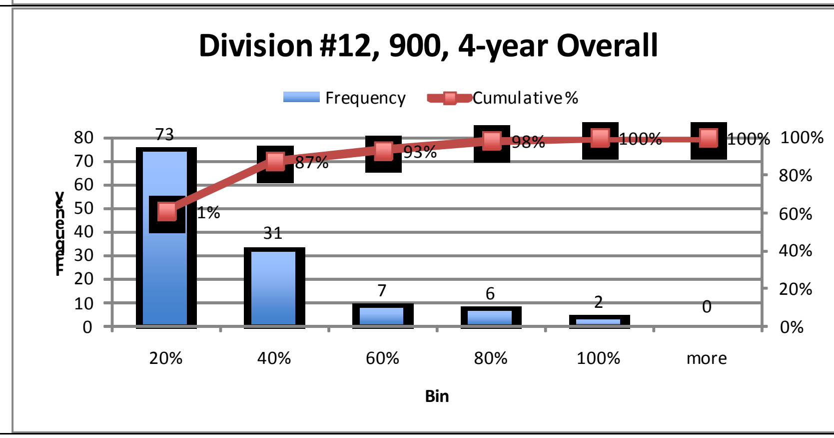

Division #7, 900, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
106
43
10
5
0
2
91%
97%
100%
100%
100%

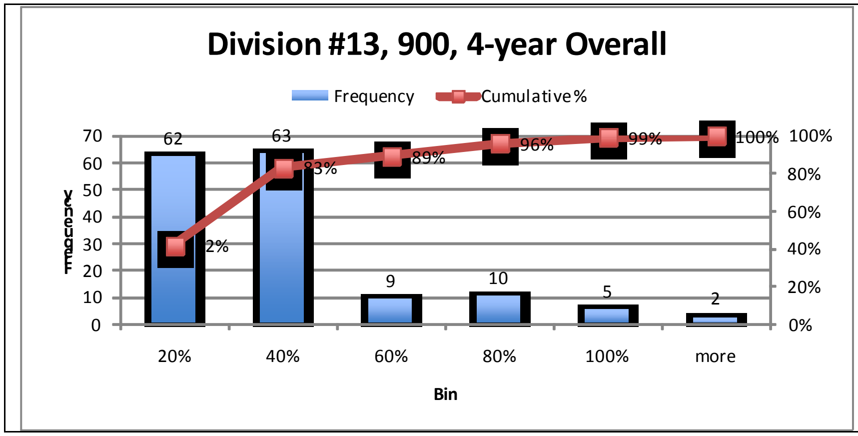

Division #8, 900, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
40
42
27
16
5
3
83%
95%
98%
100%

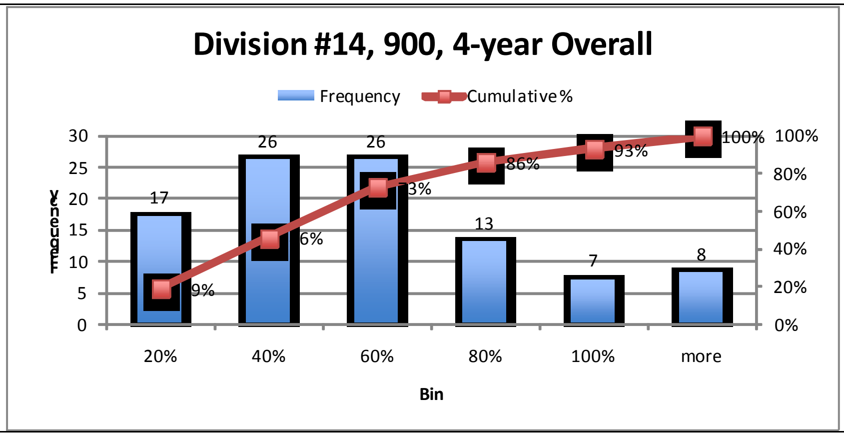

Division #9, 900, 4-year Overall
Frequency
Cumulative %
44
38
13
1
0
0
99%
100%
100%
100%
85%
20%
40%
60%
80%
100%
more
Bin


Division #10, 900, 4-year Overall
Frequency
Cumulative %
32
43
19
0
1
1
98%
98%
99%
100%
20%
40%
60%
80%
100%
more
Bin


Division #11, 900, 4-year Overall
Frequency
Cumulative %
42
56
31
19
10
2
81%
93%
99%
100%
20%
40%
60%
80%
100%
more
Bin

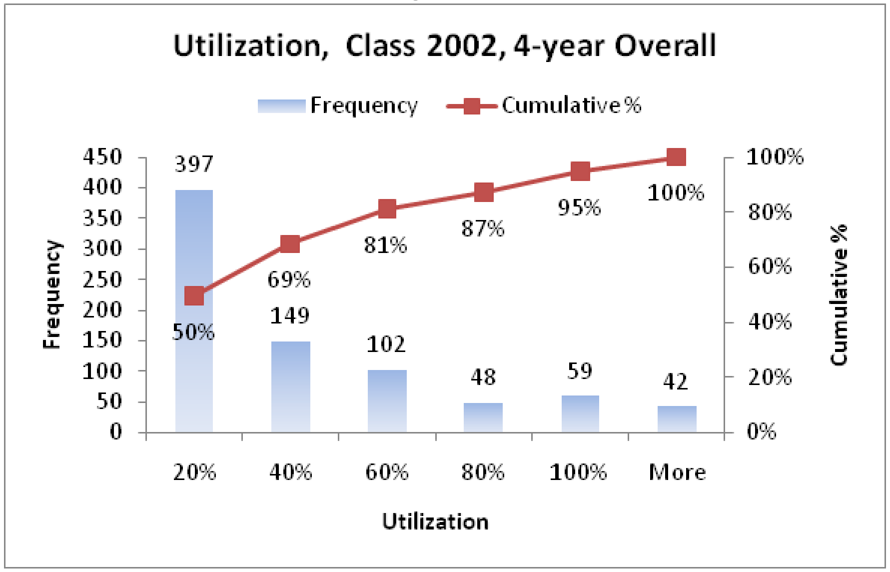

Division #12, 900, 4-year Overall
Frequency
Cumulative %
73
31
7
6
2
0
87%
93%
98%
100%
100%
20%
40%
60%
80%
100%
more
Bin


Division #13, 900, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
62
63
9
10
5
2
83%
89%
96%
99%
100%

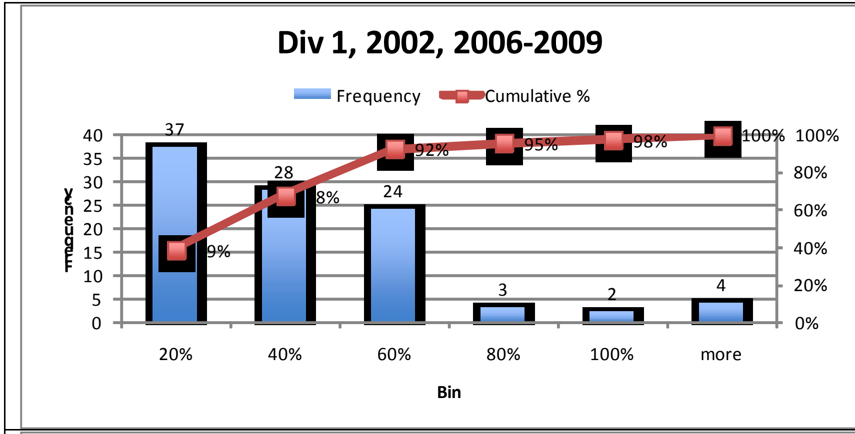

Division #14, 900, 4-year Overall
Frequency
Cumulative %
Frequency
Bin
20%
40%
60%
80%
100%
more
17
26
26
13
7
8
86%
93%
100%

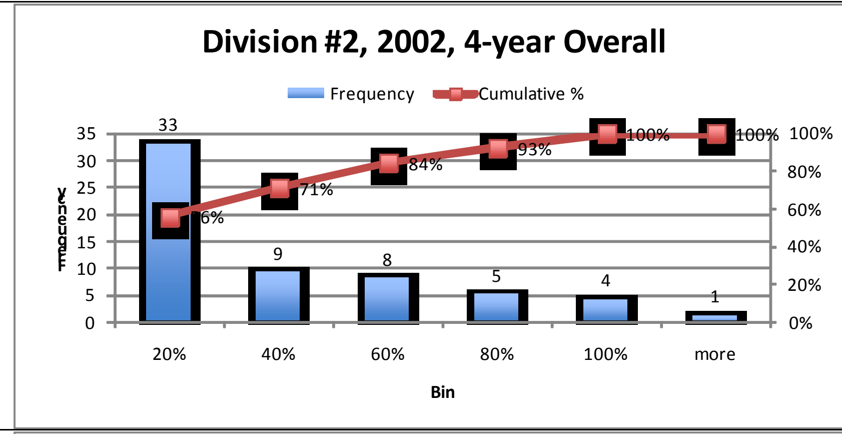
Utilization by Division- Class 2002 front end loader

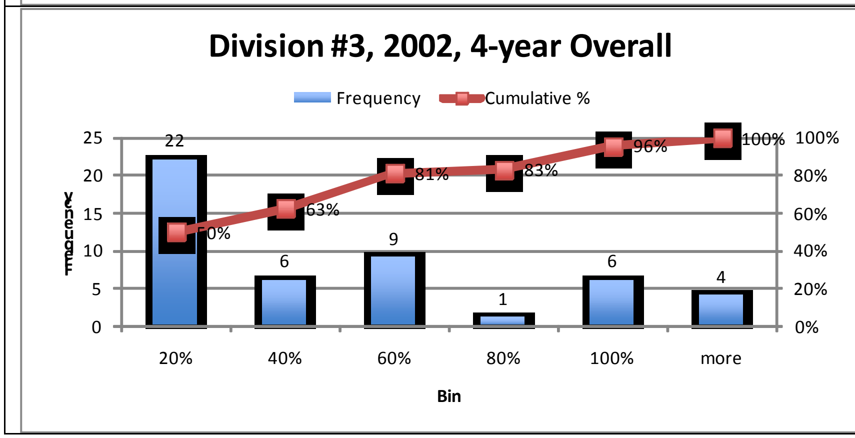
A. 2006-2009 Statewide Average Utilization

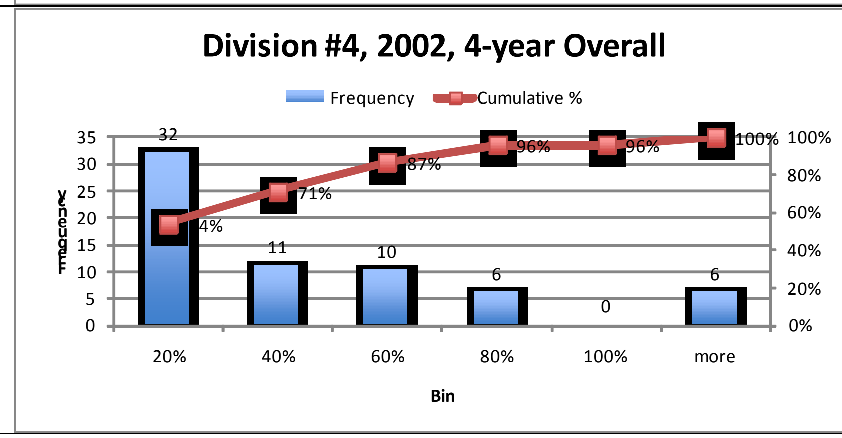


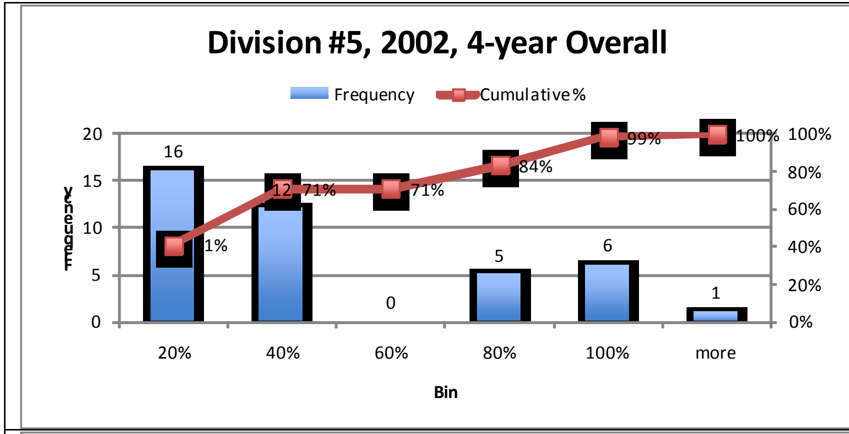
B. 2006-2009 Division Average Utilization

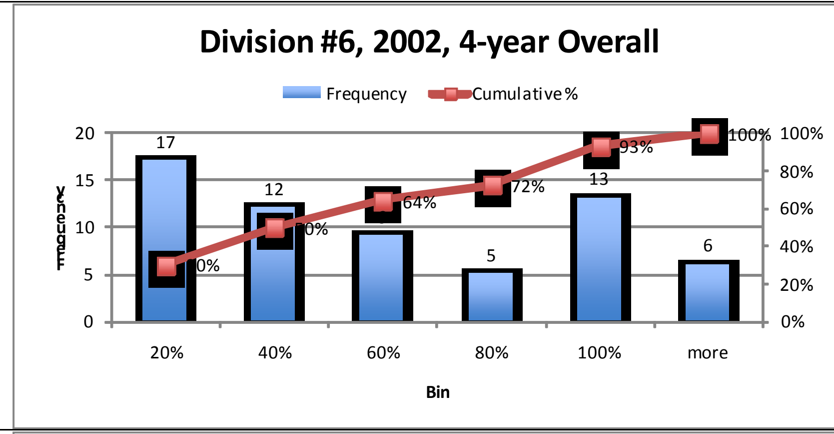

Div 1, 2002, 2006-2009
Frequency
Cumulative %
37
28
24
3
2
4
9%
8%
92%
95%
98%
100%
0
5
10
15
20
25
30
35
40
0%
20%
40%
60%
80%
100%
20%
40%
60%
80%
100%
more
Bin

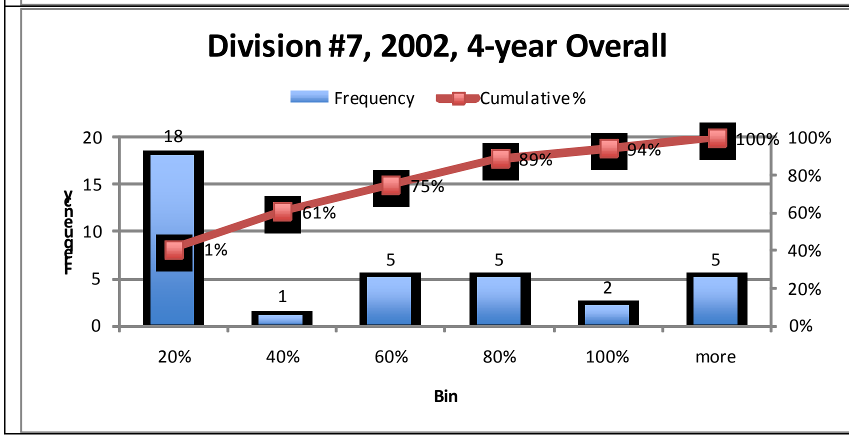

Division #2, 2002, 4-year Overall
Frequency
Cumulative %
33
9
8
5
4
1
6%
71%
84%
93%
100%
100%
0
5
10
15
20
25
30
35
0%
20%
40%
60%
80%
100%
20%
40%
60%
80%
100%
more
Bin

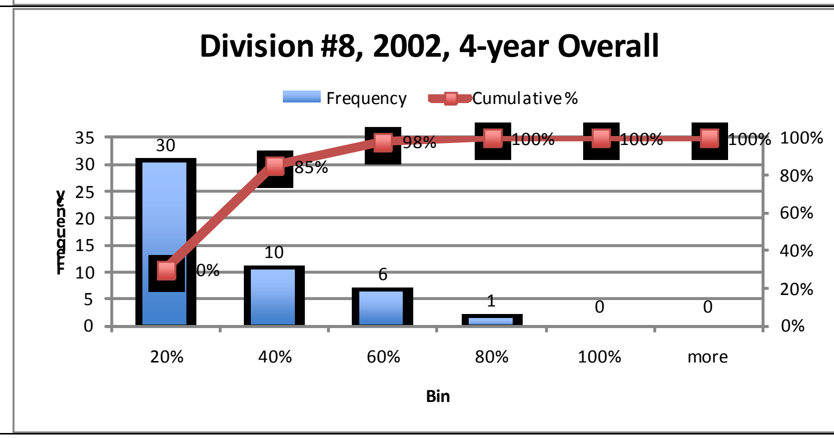

Division #3, 2002, 4-year Overall
Frequency
Cumulative %
22
6
9
1
6
4
50%
63%
81%
83%
96%
100%
0
5
10
15
20
25
0%
20%
40%
60%
80%
100%
20%
40%
60%
80%
100%
more
Bin

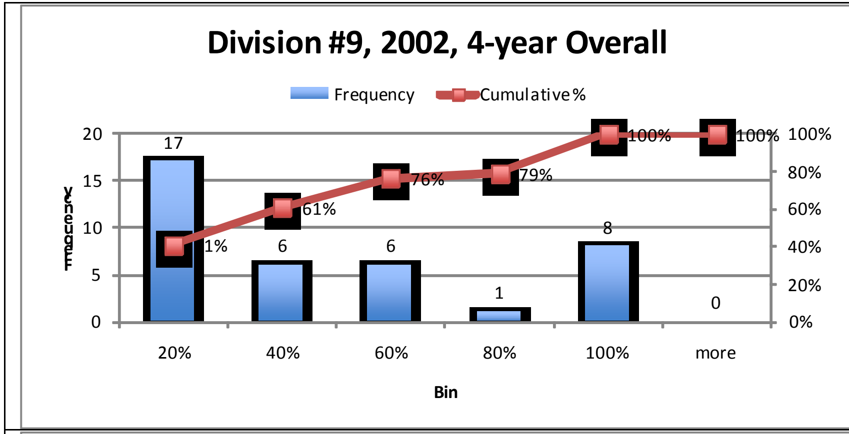

Division #4, 2002, 4-year Overall
Frequency
Cumulative %
32
11
10
6
0
6
4%
71%
87%
96%
96%
100%
0
5
10
15
20
25
30
35
0%
20%
40%
60%
80%
100%
20%
40%
60%
80%
100%
more
Bin

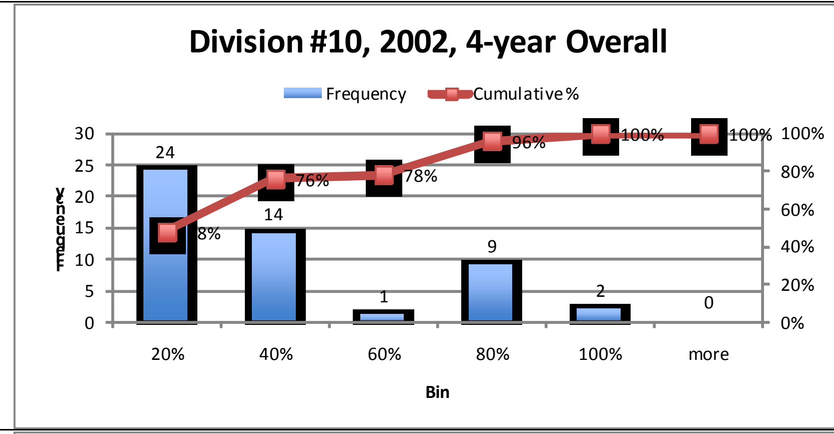

Division #5, 2002, 4-year Overall
Frequency
Cumulative %
Bin
20% 40% 60% 80% 100% more

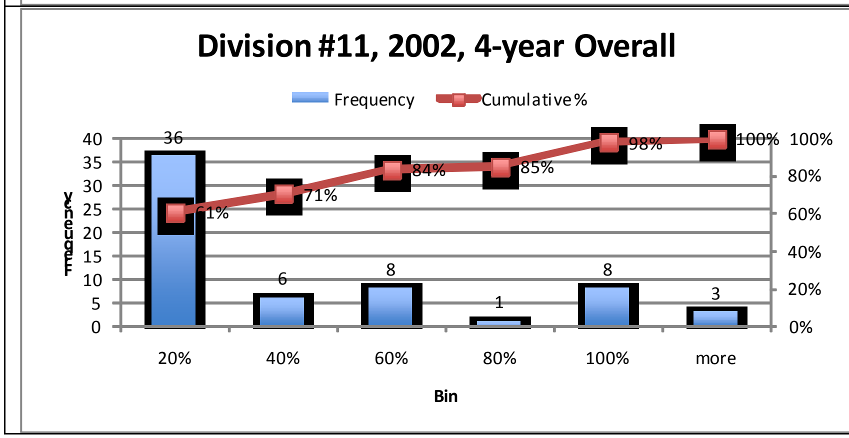

Division #6, 2002, 4-year Overall
Frequency
Cumulative %
Bin
20% 40% 60% 80% 100% more

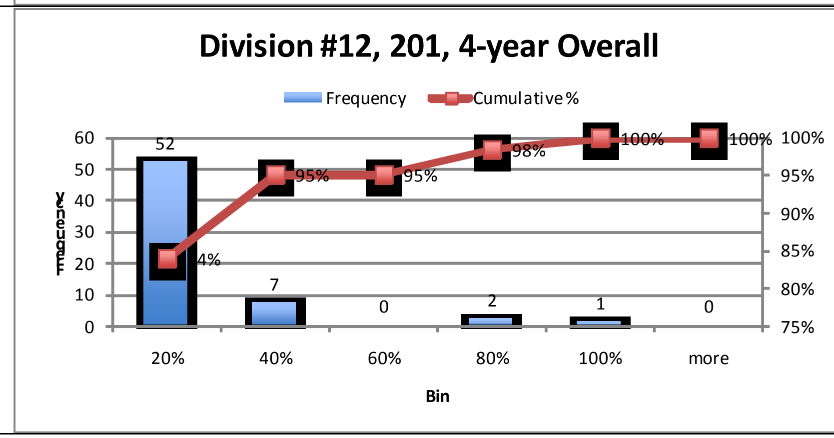

Division #7, 2002, 4-year Overall
Frequency
Cumulative %
Bin
20% 40% 60% 80% 100% more

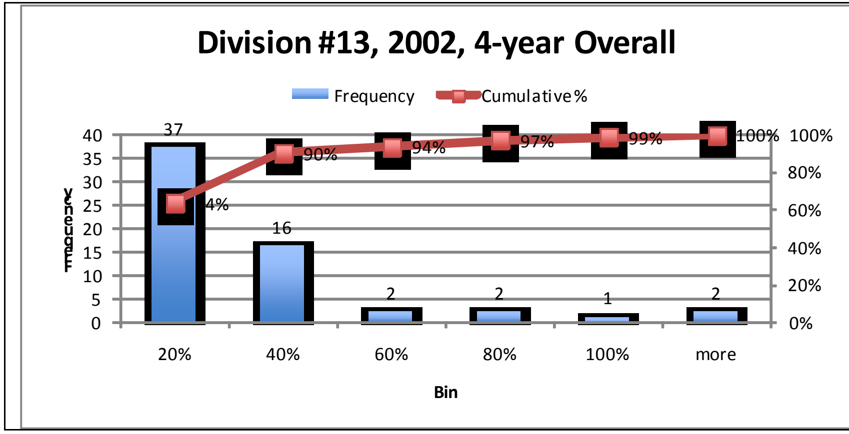

Division #8, 2002, 4-year Overall
Frequency
Cumulative %
Bin
20% 40% 60% 80% 100% more

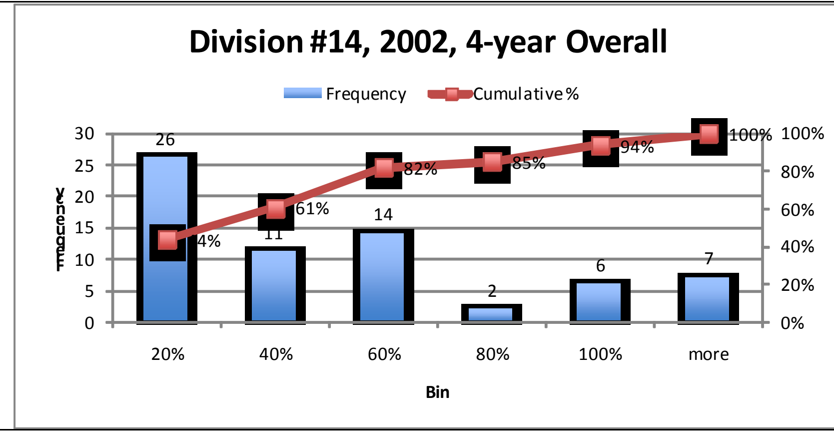

Division #9, 2002, 4-year Overall
Frequency
Cumulative %
Bin


Division #10, 2002, 4-year Overall
Frequency
Cumulative %
Bin


Division #11, 2002, 4-year Overall
Frequency
Cumulative %
Bin


Division #12, 201, 4-year Overall
Frequency
Cumulative %
Bin


Division #13, 2002, 4-year Overall
Frequency
Cumulative %
37
16
2
2
1
2
4%
90%
94%
97%
99%
100%
Frequency
Bin
20%
40%
60%
80%
100%
more


Division #14, 2002, 4-year Overall
Frequency
Cumulative %
26
11
14
2
6
7
4%
61%
82%
85%
94%
100%
Frequency
Bin
20%
40%
60%
80%
100%
more