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OPTIMAL MAINTENANCE CREW COMPOSITION AND ENHANCEMENT OF CREW PRODUCTIVITY

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Civil Engineering

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by
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Accepted by:
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ABSTRACT

The South Carolina Department of Transportation (SCDOT) dedicates a large portion of its budget and other resources to the maintenance of the State's transportation infrastructure. In order to maximize the efficiency and productivity of the State's highway maintenance workforce, the SCDOT partnered with Clemson University to research the performance of these maintenance crews. The goal of this research is to identify optimal crew compositions, if possible, and to suggest potential crew productivity enhancement methods.

Data was collected from the SCDOT Highway Maintenance Management System (HMMS) and crew rankings were developed based on several pre-determined performance criteria. These rankings were then used to identify the top performing crews based on work type and county location. Once crew rankings were developed, the performance of the top crews was analyzed to determine which crew configurations produced or yielded optimum results. Equipment utilization was also analyzed in order to improve equipment allocation specifications. A detailed survey of the SCDOT maintenance workforce was conducted at six county maintenance offices to supplement the HMMS data and further generate descriptors and characteristics of the top performing crews. The counties examined in the survey were chosen in order to provide a sample representative of the various areas throughout the State: predominately urban counties, mixed urban and rural counties, and predominately rural counties. Both maintenance workers and maintenance engineers participated in the survey with a total of 382 surveys collected. The data collected therein included demographic information on each worker,

information about crew composition, and opinion data relating to maintenance performance standards and the workers' understanding thereof.

The data analysis has produced mixed results. Performance varied from crew to crew inconsistently as different performance criteria were analyzed. Labor productivity and workforce performance are sensitive to many contributing factors making the measurement and analysis inherently difficult. The most significant performance factor was found in analyzing the cost per unit accomplished. This factor, when sorted by county and activity type allowed the generation of an Activity Composite Score (ACS) that allowed crews to be compared on a consistent basis. This analysis determined that, although there is a large degree of variation, for specific activity types there is a general crew size that tended to produce better performance scores. Using the ACS, the five top-performing crews in each county type and by each activity type were determined. A significant recommendation would be to analyze these top crews using the survey in this report and other tools to determine what characteristics of these workers and crews contribute to their higher levels of performance. An analysis of this type may generate key components and characteristics that could be replicated to possibly increase productivity and performance in maintenance crews throughout South Carolina

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CHAPTER I

INTRODUCTION

A large portion of a state's Department of Transportation budget, labor and resources go into the maintenance and upkeep of roads. Asphalt must be patched, bridges repaired, roads resurfaced, ditches cleaned, as well as numerous other activities that are essential to the State's transportation infrastructure. The workforce used to perform these activities varies, but maintenance crew performance standards are often developed at the state level for counties to apply to their crews. The South Carolina Department of Transportation (SCDOT) partnered with Clemson University to further analyze the performance of its maintenance crews. The goal of this research effort is to determine the most efficient and effective crew compositions possible. Currently, there is a loose structure upon which the SCDOT maintenance crews are organized. Each county across the state has a resident maintenance engineer who has discretion to use available budget and resources in order to organize and manage their crews. Crew size and structure varies by county, but most often a county will have one or more crews that perform a specific set of activities. Each crew has a foreman and crew members of varying experience and positions. The objective of this research is to determine how to streamline crew size, associated equipment and resources in order yield optimal results according to the location and type of work performed.

There is a vast body of literature in the research community addressing labor productivity. Most of this research identifies worker motivation as a key factor in maximizing productivity. Generally laborers arrive at work motivated, however, there are factors present in most workplaces that de-motivate workers and have a negative impact on their productivity (The Business Roundtable, 1982). Several research projects have focused on how to implement programs designed to further motivate workers, but they have had mixed results (Wilkins, 1995). There is no one program or set of guidelines that achieves the level of worker motivation needed to produce consistently-high labor productivity levels. Furthermore, research indicates that an additional reason for the widely varying levels of labor productivity is the lack of a standard and accurate set of metrics (Ellis, Ralph D. and Lee, Seung-hyun; 2006). This lack of metrics makes measurement of labor productivity difficult. These problems, along with the infinite number of variables that affect labor productivity, make it extremely difficult to effectively address the issue.

Highway Maintenance Management System

South Carolina DOT utilizes an electronic system called the Highway Maintenance Management System (HMMS) in order to keep track of all aspects of the maintenance work performed across the State. The system is designed to monitor the labor, equipment and resources used by each crew for all of the work performed. At the end of each workday, the crew foreman will fill out a Daily Work Report (DWR) that contains all of the information regarding the crew's work and performance. This information includes costs incurred by labor, equipment, resources used, the location of the work performed, the type of work performed, units of accomplishment, and the time required to complete the work. The HMMS system compiles this data for each crew and normalizes the data in order to compare crew performance according to consistent (uniform) criteria. The engineers at the DOT use this data to budget for the following fiscal year, as well as to track crew performance. One advantage of this system is that the data can be organized, sorted and viewed according to the needs of the user. The data is often used to compare a crew's performance to a set of standards developed by the State's engineers. Despite the volume of data collected, it remains difficult for the DOT to determine whether or not their allocation of resources and crews are producing optimal results. The development of optimal crew compositions and standard crew sizes to improve productivity is the overarching goal of this research endeavor. If able to more effectively utilize the maintenance workforce and equipment, SCDOT can improve productivity, reduce costs, and make efficient use of resources for the road infrastructure of South Carolina.

Problem Statement

SCDOT currently has no specific requirements with respect to the composition of maintenance crews. Crews are assigned by the county's residence maintenance engineers using his/her knowledge of the available workers, workload, and budget. When analyzing the output of maintenance crews across the state, a wide range of performance levels are observed. While there are many factors that will impact a crew's labor productivity (addressed in further detail in the literature review), for this research, the emphasis has been placed on determining the best possible crew composition for a given activity. Several different objectives were presented to the Clemson University Research Team in the original proposal in order to provide structure and guide the research being conducted:

- Determine the crew configurations and associated equipment resources, using objective data to the maximum possible extent, to optimize crew productivity and efficiency
- Determine the factors that impact labor crew productivity, and whether or not revised policies and procedures would improve productivity
- Determine if productivity standards are clearly understood by crew leaders, such that the work performed is recorded correctly by activity, work description and according to even units of accomplishment in HMMS

After a thorough literature review, the HMMS system was used to provide the research team with several years of performance data for different maintenance crews across the State. The team also developed a workforce survey in order to gain a better understanding of the maintenance workforce such as background, experience and opinions regarding performance standards and the attainment of thereof.

CHAPTER II

LITERATURE REVIEW

Introduction

A thorough literature review was conducted to facilitate this project. Two major areas were researched: the measurement of labor productivity, and the motivation of craft workers. These two areas should offer the most information in order to provide direction in developing standard procedures for both defining and measuring productivity within the SCDOT, a more complex problem than just measuring the number of workers in a crew.

The majority of the documents used for the literature review came from online databases. The Transportation Research Information Services (TRIS) database provided the bulk of the information. It is the world's largest and most comprehensive bibliographic resource on transportation information. Once appropriate keywords were determined, hundreds of resources were sorted and the most applicable ones were obtained for the purpose of the research. Other pertinent resources used were the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO) and the Clemson University Library databases. In addition, several human resource publications were consulted.

Labor Productivity: Measurement

The literature review had to be divided into two separate parts because there is little data that addresses the exact problem addressed in the research at hand. No background information could be found that specifically addresses the types of crew makeup typical of SCDOT highway maintenance crews. Thus, one of the problems with the search was finding data that was relevant to the research at hand, which could be used to help determine a more appropriate research direction. In addition, a good understanding of the definition of labor productivity, and how it is measured, was needed in order to correctly formulate a hypothesis for the research. This question has been addressed and "answered" by many different studies over the past few decades, but there is still no consensus on an applicable definition by the research community specific to transportation maintenance.

One of the first documents that seemed applicable was a recent study by the Federal Highway Administration (FHWA) on the development of a Maintenance Decision Support System. The Maintenance Decision Support System (MDSS) project was designed to provide a decision support tool that will give recommendations on road maintenance courses of action. The system was developed by several private sources with funding from the FHWA and was first implemented by the Iowa DOT. The system is the first of its kind and demonstrates that new technologies are available and able to assist managers with maintaining safety and mobility (Murphy, Ray; 2006). The system's software can provide users with a range of information including:

- Timing information about the start and duration of precipitation, including the conditional probability of snow, rain, and ice
- Information on the type and amount of expected precipitation
- Optimized treatment times
- Recommended treatment types and dispersion rates
- Assistance in the establishment of work completion incentives

An additional report was conducted by a private consulting company, ERES Consultants Inc., for the National Cooperative Highway Research Program, the Transportation Research Board, and the National Research Council. The idea behind the study was to identify specific requirements that are needed for a successful highway maintenance program. A question and answer study was performed and requirements for the program were developed. The main focus of the program was the implementation of systematic maintenance management procedures which are organized by the head engineers of a district, in coordination with their maintenance foreman. Desired results should be identified and defined at the onset of the program. These results could be for several different timelines (i.e. weekly, monthly, and yearly) but should be concrete and clear. The procedures required to accomplish defined work (performance standards) should also be established at this time (Smith, K.L., Stivers, M.L., Hoerner, T.E., and Romine, A.R.; 1997). These requirements correspond to the issues raised by several of the SCDOT maintenance engineers who were interviewed during the research process. It is also aligned with the fact that labor crews are being measured specifically on their ability to meet standards which are set by their specific county resident maintenance engineers. These productivity standards are initially set by the State and then revised by the engineers (if deemed necessary). The report illustrates examples of how to define the work accomplished and thus theoretically will result in improved, more accurate and more feasible productivity standards for maintenance crews. It should be noted that this system is not outlined in great detail and that it leaves a great deal of choice up to the district and/or state. All, or just a few, of the requirements may be used and should obtain positive results. The data is drawn from reports of several state departments of transportation that have implemented pieces of the system with favorable results. The report does not specify any data obtained from an implementation of their program as a whole.

Harry Hatry conducted a study of the status of labor productivity measurement in the public sector. The study, although dated, provides good definitions of productivity measurement. Hatry defines the key measurements of productivity as the combination of efficiency and effectiveness. He then further breaks down efficiency into its various forms, such as the ratio of number of units of work accomplished per unit of input, utilization-availability measurements, ratio measures that consider the quality of output, and productivity indices. Hatry goes into further detail of how the public sectors differ, rarely using effective productivity measurement. He believes this can be attributed to several factors. The first is that productivity measurement is not as important to the public sector because of the bureaucratic nature of the work structure and environment. Secondly, he believes that individuals working in the sector do not have a firm grasp of exactly what productivity is, and thus shy away from trying to make any measurements and/or improvements in this area (Hatry, Harry; 1978). This study is applicable to the research at hand because a good definition of labor productivity is necessary in order to optimize highway maintenance crews.

Assuming that one has now established definition for labor productivity, the question of measuring it remains. The Construction Industry Institute (CII) has done multiple studies on labor productivity measurement using data from many large construction projects across various disciplines. While this may not specifically apply to highway maintenance crews, it still offers a better idea of how to determine the productivity of craft workers. One such study was conducted at the University of Texas at Austin for the Bureau of Engineering Research. The report was intended to be an introduction to labor productivity. It presented a simple approach to productivity measurement with several goals in mind: to be simple and inexpensive to implement and maintain, to be timely in providing problem indicators, and to be independent of other business systems. The study recognized the importance of selecting activities, reporting quantities, and reporting work hours in order to accurately measure productivity (Construction Industry Institute; 1990). A decade later, an additional report was published to illustrate different production planning strategies that can be employed to increase labor productivity. The report found that a primary reason for decreased productivity across all types of construction was resource availability; workers didn't have the proper resources available to them when needed. Waiting on equipment and/or not having the proper resources for the work at hand is one of the major factors leading to the decrease in labor productivity (Construction Industry Institute; 2001). This issue was also identified in some of the initial interviews conducted with field workers for this research.

In another related study, published in the Journal of Management in Engineering, Rojas and Aramvareekul conducted a survey of owners, contractors, and consultants in order to determine labor productivity drivers and opportunities to increase labor productivity. The report concluded that management skills and manpower issues were the primary concerns with regards to labor productivity. External factors such as weather or equipment availability were considered to have a relatively minor impact on productivity. According to the survey responses, the five most promising opportunities believed to help increase labor productivity were: (Rojas, Eddy M. and Peerapong, Aramvareekul; 2003):

- Improvement of methods
- Improvement of training programs
- Enhancement of worker motivation
- Improvement of strategic management
- Improvement of procurement management

This report contrasts the research conducted by CII, citing the internal factors of a construction project as most detrimental to labor productivity, rather than external factors.

Finally, a more focused study titled “Measuring Project Level Productivity on Transportation Projects” was published in the Journal of Construction Engineering and Management. It applies specifically to this research in that it provides a basis for how to begin measurement of labor productivity at the SCDOT, and gives results of several large projects that attempted to implement different labor productivity management techniques in construction. This study introduced the development of a method for measuring and analyzing the productivity level of all activities throughout the lifecycle of a project. The key aspect of the study was a measurement method and the development of a process to combine multiple concurrent work activity productivity values into global productivity values for the project as a whole. Three case studies, covering thousands of productivity values, were performed on highway construction projects to demonstrate and test the validity of the analysis method. Results indicated that productivity can be measured and analyzed at the project level based on the field data of construction operations. They also suggest that this is the most effective method of measuring productivity across a large construction project in the transportation industry (Ellis, Ralph D. and Lee, Seung-hyun; 2006). While individual SCDOT districts typically subcontract very large construction projects, this study shows that measuring productivity at the field level (such as individual maintenance crews) is preferable, instead of looking at SCDOT worker productivity output as a single entity.

Labor Productivity: Motivation

Once labor productivity has been defined and proper procedures are in place to effectively measure the productivity of workers at the field level, the motivation of craft workers must next be examined. In order to fully understand how to motivate highway maintenance crew workers, it is important to identify some of the typical de-motivators of laborers in the construction industry. One of the most applicable reports available illustrating typical de-motivators across different types of construction projects was published in the Business Roundtable. These de-motivators include:

- Lack of material
- Project confusion
- Communication breakdowns
- Rework
- Unavailability of tools and equipment
- Disrespectful treatment
- Lack of recognition

- Little participation in decision making
- Lack of cooperation among crafts
- Incomplete engineering
- Restrictive or burdensome procedures and regulations
- Poorly trained foremen
- Restrictive work practices in labor agreements

All of these factors are relevant in that they affect the SCDOT workers. The report further states that labor workers will motivate themselves given the right conditions and opportunities. Findings of The Business Rountable studies indicate that having properly trained supervisors and open communication will greatly increase labor motivation and thus productivity (The Business Roundtable; 1982).

Another report was published in the Journal of Construction Engineering and Management titled “Fundamental Principals of Workforce Management.” The authors, Horman and Randolph, addressed workforce management as a general concept across a broad spectrum of construction related projects. The report was derived from the authors’ combined 25 years of experience in observing over 125 different projects. The authors examined the issues that they believed most affected worker productivity. These issues included scheduling, crew structure, tool selection, resource allocation, the responsibility given to the craft workers by the foreman/supervisors, and the necessary inclination to strive for symbiotic work relationships between craft workers and foremen/supervisors. The overarching purpose of the report was to illustrate ways to motivate workers and eliminate costly disruptions of work flow. The authors acknowledged that while each case was unique, they believe that these principles will greatly reduce costs and improve worker efficiency (Horman, Michael and Thomas, Randolph; 2006).

In recognizing the importance of the relationship between foremen/supervisors and their workers, one study by Amir Hanna illustrated how proper training of people in leadership resulted in increased labor productivity. This increase was due to the motivation of workers on an individual basis. Titled "Effective Motivation of Highway Maintenance Personnel: Tools for Peak Performance" and published in the Research Results Digest, the study found that properly trained supervisors had happier workers with higher motivation and productivity. It outlined a program designed to help supervisors manage their workforce more effectively by placing emphasis on each individual employee, as well as by understanding that different responses will come from the same reward. The program was designed to help supervisors understand how to better align individuals with rewards. It gave different approaches to analyzing performance, establishing realistic goals, planning of activities, matching workers to a task, effective coaching by management, and communicating in order to identify the areas in which the personnel most need improvement (Hanna, Amir; 2001).

While still conducting the literature review for this project, two programs started at Departments of Transportation in different areas of the country which identified favorable results in the motivation of craft workers. These programs may provide information that could help the SCDOT increase its craft worker productivity and identify the best way to optimize its maintenance crews. More importantly, these programs have already proven to be effective in transportation construction work. The first report was written about a program implemented by the North Carolina Department of Transportation (NCDOT), titled “North Carolina DOT’s Skill-Based Pay Program: A Working Model for Training and Compensating Highway Workers.” The goal of the program was to create a force of highly-trained workers across various skill levels, which would keep NCDOT competitive in the market. The program promoted flexibility and equity in broad, generic job classifications that met employee and NCDOT's training needs. The program was built on "skill blocks" which are unique sets of tasks and duties. These skill blocks were categorized as entry, intermediate, journey, and advanced levels. Each was assigned a set dollar value, and was achieved through a four-step process: testing, on-the-job training, certification, and compensation. In this system, employees advanced through the four levels, but still remained in the broadly defined class of Transportation Worker. The program created enthusiasm among workers, who, in turn, drove the program (Aschbrenner, D.R., Domico, D. and Fountain, A.M.; 2000).

The second study provides a summary of the Oregon DOT’s experimental program with self-directed labor crews. The program starts with a reduction in first-line supervisors, from 21 supervisors to seven area maintenance managers (AMM’s). Each AMM oversees the operation of three crews. Each crew is expected to prepare a work plan covering 30 days, 60 days, or a year. The plan is then negotiated and agreed upon with the AMM. Each AMM has one area coordinator that handles most of the routine paperwork, performance tracking and reporting, thus removing much of the paperwork from the crew team level. Surveys of the employees who participated in this program showed favorable results, and metrics used to measure worker productivity showed an improvement (Wilkins, S.; 1995). The SCDOT should reflect on these programs and possibly certain procedures for its own craft workers. These programs demonstrate a relatively inexpensive and effective way to create enthusiasm and motivate workers. This would likely result in a noticeable increase in productivity among workers, and may also yield benefits such as reduced turnover rates and decreased need for direct supervision of work crews.

Some of the best information on craft labor motivation can be found in a book titled Productivity Improvement in Construction written by Gregory Howell, Clarkson Oglesby, H. Clarkson, and Henry Parker. Still one of the preeminent books on the topic of construction labor motivation, it is based on the premise that changing management techniques and operating procedures will improve on-site productivity. The data therein comes from years of research by the authors. One of the primary points of the book is that there exists a strong relationship between labor productivity and job satisfaction among construction workers. For the construction industry, a productive job creates high job satisfaction, while a nonproductive job, or jobs that are behind schedule, produce dissatisfaction at all levels of the management/worker chain. This relationship is the inverse of that which is found in an office or factory setting, which states that high job satisfaction leads to greater productivity. This inverse relationship is believed to be due to the very nature of construction. In construction, workers, through their own efforts, produce a highly visible, physical structure from which great satisfaction can be derived upon completion. For instance, jobs that are well-planned and run smoothly produce overall satisfaction, while jobs with poor management often create dissatisfaction. The book goes into great detail of ways to improve productivity across all areas of a construction project. Specific details are given for owners, management and laborers.

The primary focus is on setting formal goals for all workers and establishing procedures that allow for excellent communication and cooperation so that job productivity is at its highest level. The research shows that worker satisfaction comes with this productivity. Other results include higher labor retention rates, a greater level of skilled workers and lower costs, which lead to higher profits. Additional areas addressed are safety, environmental health and newer technologies (i.e. computers in 1989), and how they can be used in the context of practices described in the book. While there are many different aspects of this book, the most relevant example, in terms of SCDOT's purposes, is that communication and high satisfaction will produce a significant increase in worker productivity. While this may appear to be a daunting task, even modest improvements in either of these areas will improve productivity of maintenance crews, thus allowing SCDOT to adjust its standards accordingly (using proper metrics). This will in turn enable the composition of the crews to be adjusted if necessary (Howell, Gregory A., Oglesby, Clarkson H. and Parker, Henry W; 1989).

CHAPTER III

METHODOLOGY

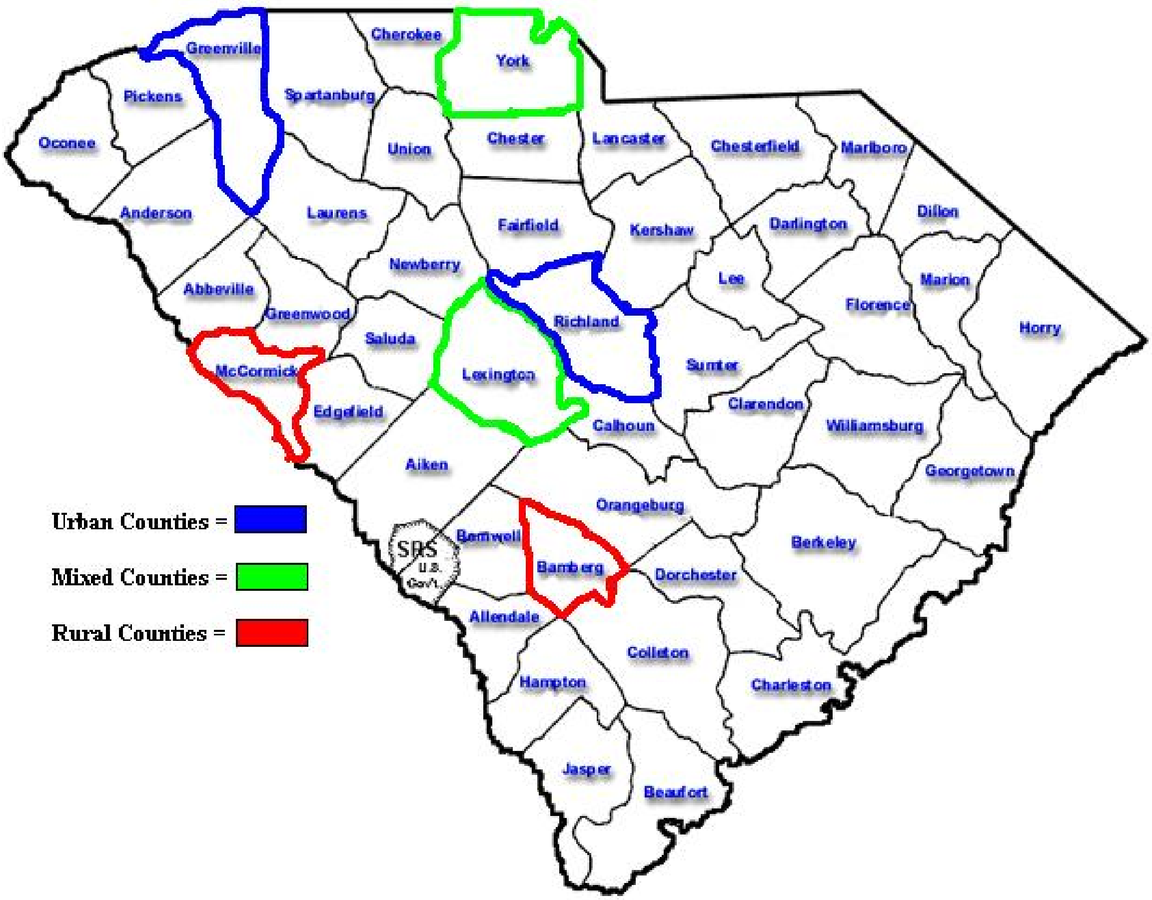
Mr. David Cook, head SCDOT maintenance engineer, led the Research Steering Committee for this project composed of engineers employed by the SCDOT. The purpose of the Committee was to provide direction and feedback to the research team with regards to its performance throughout the duration of the project. Progress reports were forwarded quarterly to the Research Committee in order to provide updates as to the progress of the research. During the course of the research, developments in the data findings led to meetings that changed the nature of the project considerably and narrowed the scope of the data analyzed. The data and feedback provided by the Research Committee was invaluable in finding the necessary information for the successful completion of the research at hand.

Data Analysis

In order to effectively analyze the large amount of data available in HMMS, a representative sample of data was chosen to reflect a cross-section of the state's maintenance workforce. South Carolina has distinct geographical characteristics; therefore, it was important to consider the locations of the crews chosen for analysis. Discussion with the SCDOT engineers led to the selection of crews from three different types of counties – primarily urban, mixed urban and rural, and primarily rural. Per the recommendation of the DOT engineers, the counties chosen for analysis were 1) Urban: Greenville and Richland; 2) Mixed: Lexington and York; and 3) Rural: Bamberg and

McCormick. Figure 1 shows a map of all the counties within the state of South Carolina with the six counties chosen for analysis highlighted:

Figure 1: Map of South Carolina Counties



These counties were chosen due to the differences in population, and landscape. For this reason, there are significant differences in the work being performed by the SCDOT maintenance crews in these areas. The populations of the six counties chosen are (South Carolina Budget and Control Board: Office of Statistics):

- Greenville: 379,616
- Richland: 320,677
- Lexington: 216,014
- York: 164,614

- McCormick: 16,658
- Bamberg: 9,958

Additionally, there are different work criteria and expectations put on the maintenance crews at each of these different locales. For example, in the more urban counties there are greater numbers of workers available to a maintenance engineer. This gives the engineer greater flexibility when assigning workers to their crews. Generally, this means that the SCDOT maintenance engineer will choose to have crews narrow the scope of their work to a few specific activities. The idea behind such organization is that specialized work crews will yield greater productivity. Crews in an urban environment will face greater challenges due to traffic congestion. There is generally a greater need for signage and signals in these areas due to a greater number of intersections requiring additional work. Accidents will be more frequent, roads will deteriorate more quickly and in general, the infrastructure maintenance will require a greater amount of labor and planning to maintain a safe and healthy road system. At the opposite end of the spectrum are the rural counties which generally have a much smaller number of workers available to a resident maintenance engineer. This results in crews having to perform a wider variety of activities. While a rural county may not have the traffic congestion, road wear or signage/signals of the urban counties, there are a different set of obstacles for the crews to address. There are generally many more miles of road to maintain per worker in these rural counties. Often it may be necessary to travel further to reach a jobsite. Upon arriving at the site, the equipment and resources available to a rural crew are generally less than those of their urban counterparts due to less funding for road maintenance in these areas. However, the lack of traffic congestion and the associated compressed schedule allows for a work environment that is less stressful. All of these factors impact the labor productivity in the different areas chosen for analysis. They change day to day and every situation is different. The HMMS system does not address the majority of these factors, making comparisons of productivity in different areas of the State difficult. The selection of these counties was intended to capture a large amount of useful data for the research that will reflect all of the different factors affecting maintenance crews across the State.

Once the HMMS data was selected, it was necessary to identify all criteria available for the performance analysis of the maintenance crews. The data retrieved from the system provided several possible alternatives that the research team could investigate in order to perform a comprehensive analysis of the crews. As noted in the literature review, there are many different ways in order to analyze the performance of a crew. In order to effectively analyze the crews and discern any trends in data that demonstrate the characteristics of the best-performing crews, the data was analyzed using as many different performance measures as possible. Once the best crews are determined using these performance characteristics, the better performing crews will be identified and their compositions noted. These better performing crews will then be used as a model for crew compositions for similar activities. It is possible that additional analysis of these crews, beyond the scope of this investigation, could generate more insight as to the characteristics of these better performing crews and why exactly they perform better compared to similar crews across the state.

Initially, HMMS data was used to compute the following crew performance measures for each of the crews in the counties for this analysis:

- Cost per employee (Cost/Emp)
- Cost per hour of work (Cost/Hr)
- Cost per daily work report (Cost/DWR)
- Accomplished work per employee (Accomp/Emp)
- Accomplished work per hour (Accomp/Hr)
- Accomplished work per daily work report (Accomp/DWR)

Crews were then ranked based on each of these different performance criteria. To analyze each crew based on all six performance criteria, a performance index number (PIN) was developed to provide the SCDOT with an overall performance evaluation for each crew. The performance index number is the average of the crew's ranking in each of the six performance areas when compared to other crews across the six counties. Using this system, a lower number will show that a crew is performing at a higher level.

The variations in the other performance criteria led the Research Committee to determine one performance criteria that could be analyzed in greater detail. The 'cost per unit of work accomplished' criteria involved the creation of an Activity Composite Score (ACS) that compared crews by county type and work description. Three activity descriptions with sufficient data for analysis were chosen for this comparison – shoulders and ditches, surface repair, and driveway work. These activity descriptions were chosen because they cover a large portion of the daily work that the maintenance crews across the State perform. Each activity description is further broken down into work descriptions. For each type of work description, a DWR is completed and filed by a crew foreman. The Activity Composite Score was computed based on crew performance for all work descriptions contained within each of these activities. The score is simply the average of the ranking achieved by each crew for all of the work descriptions in which they recorded a DWR. If a crew had recorded DWR's for less than four different work descriptions within an activity description, the size of the sample data was not deemed to be large enough to be given an activity composite score. The crew rankings for the work descriptions were computed using the activity descriptions' average cost/unit accomplished for all DWR's filed during the three fiscal years over which data was gathered. All crews were ranked based on this score and the top performing crews were identified. The size of each crew was plotted against the ACS to determine if better performing crews (i.e. those with a lower ACS) also indicated a certain optimum number of workers.

An equipment optimization analysis was also performed using HMMS data gathered from the six counties analyzed. The equipment used by each crew for an activity was recorded in an HMMS daily work report (DWR). Examination of equipment usage throughout the data provided allowed the research team to recommend changes to the equipment specifications by eliminating equipment that was not deemed necessary. Eliminating equipment for a given work description that is used less than 50% of the time would significantly improve the equipment optimization desired by the SCDOT. Tables were generated and organized by work description, crew, and county indicating the revised equipment recommendations for each work description.

Crew Survey

There are many factors that impact the performance and productivity of construction workers. In order to effectively determine optimum crew configurations, an understanding of the overall workforce is necessary. A questionnaire was developed based on a survey conducted of skilled construction craft labor by CII in 2002 (Brandenburg, 2006). It was administered on site at each of the maintenance offices for the six counties examined in this analysis. The survey was designed to gather information pertinent to the analysis of the maintenance crews' performance characteristics across the state. Workers were asked to provide responses to questions regarding their personal educational background, work experience, technical knowledge, opinions on the SCDOT, opinions of their crew and their individual performance.

The surveys were handed out in each of the six counties in the morning during weekly safety meetings. This allowed the researcher to observe the survey administration as well as converse with the workers and maintenance engineers. Many workers took the surveys seriously and were encouraged by the ability to voice their concerns, suggestions and opinions, and took the time to do so. During the administration of the survey, the researcher had an informal interview with the maintenance engineers and was able to gather their opinions, suggestions and learn more about how they chose to organize and utilize their crews and equipment. This interaction allowed for the researcher to better understand each county and how their crews operated, along with the outside factors that can greatly affect maintenance crew productivity, but are not always recorded in the HMMS system data.

A total of 382 surveys were completed by maintenance workers and maintenance engineers. This data was compiled using a Microsoft Access database that allows the SCDOT to easily retrieve, manipulate and interpret data. Some preliminary data analysis is included in this research report, however, additional data analysis and survey collection could produce information invaluable to the SCDOT regarding the composition and characteristics of the best performing crews. This information could be critical to truly understanding the basic characteristics of the SCDOT maintenance workforce and identifying potential indicators of successful individuals and the characteristics of successful maintenance crews.

CHAPTER IV

RESULTS

HMMS Crew Data Analysis

Within the SCDOT, each county has its own crew structure and organization. Tables 1 and 2 illustrate the general crew data for the six the counties examined in this report. Data from a total of 61 crews representing a total workforce of 450 employees were examined.

Table 1: General County Data

County	Total Employees
Bamberg	39
McCormick	26
York	81
Richland	121
Greenville	73
Lexington	110

The HMMS data collected for the six counties was organized by crew. For each crew there is a set of data from the HMMS activity reports which consist of the following information:

- Fiscal Year
- Equipment Cost
- Labor Cost
- Material Cost
- Accomplished Quantity
- Total Daily Work Reports
- Total Employees
- Total Hours

Table 2: General Crew Information

	Crew #	Crew Type	# Crew Members		Crew #	Crew Type	# Crew Members
York	44605	Equipment Shop	8	Greenville	32305	Equipment Shop	12
	44611	Patching/ Litter	7		32311	General	6
	44612	General	6		32312	General	6
	44613	General	6		32313	General	6
	44614	Ditches/Shoulders	7		32314	General	6
	44615	Signs & Signals	8		32315	General	5
	44616	Bridge Maintenance	5		32316	Drainage	6
	44617	Driveways/Requests	7		32320	Re-treatment	7
	44618	Driveways	7		32330	Signs	7
	44619	General	4		32331	General	9
	44620	Special Projects	7	Lexington	13205	Equipment Shop	9
	44621	IRVM/ Litter	9		13206	Equipment Shop	4
Richland	14005	Equipment Shop	12		13215	Signs/ Paint	7
	14015	Sign/ Pvt Markings	11		13220	Mow/Patch	10
	14020	General	9		13225	Drainage	7
	14025	General	7		13230	IRVM/ Herbicide	2
	14030	General	6		13240	Full Depth Patch	7
	14035	General	8		13242	Concrete	5
	14040	General	7		13245	Bridge Maint.	4
	14050	General	9		13250	Interstate	6
	14055	Litter/ Drainage	6		13260	Mow/Patch	5
	14060	Asphalt	5		13265	Drainage	7
	14065	Ditching	8		13270	Mow/Patch	6
	14070	Bridge Maintenance	6		13275	Drainage	8
	14075	Herbicide	4		13280	Ditching	6
	14080	Ditching	8		13285	Ditching	8
	14085	Interstate	4		13290	General	9
	14090	Mowing/ IRVM	11	McCormick	23305	Equipment Shop	4
Bamberg	70503	Driveways/Requests	9		23311	Drain/Drive/Patch	4
	70505	Equipment Shop	5		23312	Drain/Drive/Patch	6
	70512	Driveways/Requests	9		23313	Mowing/ROW	6
	70513	Ditches/Driveways	9		23314	Sign	1
	70515	Mowing/Requests	7		23315	Limb Trimming	5

Table 3 illustrates the crew data and how it is arranged within HMMS for a specific crew by fiscal year.

Table 3: Example Data for Crew 13230 in Lexington County

Year	**Equipment $**	**Labor $**	**Material $**	**Accomp Qty**	**Total DWRs**	**Total Emps**	**Total Hrs**
2007	$182.00	$516.00	$109.00	3.1	1	4	32.0
2005	$502.00	$394.00	$4.00	1.0	5	11	20.9
2006	$55.00	$470.00	$71.00	1.2	5	10	20.4
2007	$317.00	$1,724.00	$67.00	4.1	17	43	74.6
2005	$30.00	$71.00	$5.00	10.0	1	2	4.0
2005	$18.00	$85.00	$0.00	0.0	1	2	4.0
2006	$32.00	$132.00	$26.00	2.0	1	3	6.0
2005	$243.00	$480.00	$0.00	960.0	1	4	32.0
2006	$209.00	$1,003.00	$0.00	200.0	1	7	56.0
2007	$232.00	$594.00	$0.00	250.0	1	6	31.0
2007	$42.00	$221.00	$0.00	0.5	1	3	10.0
Sum	**$1,862.00**	**$5,690.00**	**$282.00**	**1431.8**	**35**	**95**	**290.9**
Average	**$169.27**	**$517.27**	**$25.64**	**130.2**	**3**	**9**	**26.4**

Each entry represents one type of activity for which the crew reported data during that year. The equipment column indicates the amount of money spent on equipment by the crew for activites during that fiscal year. The labor column indicates the total amount of money paid to crew members for their labor. The material column indicates the amount of money spent on materials for the given year and activity. The accomplished quantity column indicates how much work was performed by the crew during the fiscal year for the activity performed. This column has different units depending upon the activity being performed. The Total DWRs column indicates how many daily work reports were filled out by the crew that year for the given activity. The total employees column gives the number of employees that worked on the given activity for the fiscal year and the total hours is the amount of labor hours accrued by the crew while performing the given activity. (General crew information for every county is located in Appendix B)

The initial performance analysis was based on the following performance criteria:

- Cost-per-employee (Cost/Emp)
- Cost per hour of work (Cost/Hr)
- Cost per daily work report (Cost/DWR)
- Accomplished work per employee (Accomp/Emp)
- Accomplished work per hour (Accomp/Hr)
- Accomplished per daily work report (Accomp/DWR)

The cost-per-employee criteria is calculated by taking the total costs assigned to a crew for a given fiscal year (as reported in the DWRs in the form of labor cost, equipment cost and material cost) and dividing them by the number of workers in the crew. It must be noted that all crew members may not contribute to every DWR, and some DWRs may have additional workers assigned to the crew. However, these numbers yield useful information due to the one-year time frame of the data. The cost per hour of work is calculated by dividing total cost incurred by a crew by the total hours of work performed for the fiscal year. The cost per DWR is the total cost incurred by a crew for an entire fiscal year divided by the number of DWRs filed by that crew for the year. The accomplished work per employee is calculated by dividing the amount of work accomplished for a DWR by the amount of employees working in the crew. Accomplished units are different for different types of work, so these numbers will vary depending upon the work performed by the crew. The accomplished work per hour is calculated by dividing the total amount of work accomplished by the number of hours spent performing the work. Finally, the accomplished work per DWR is calculated by dividing the total accomplished work by the number of DWRs filed in a fiscal year.

Table 4 illustrates how these performance criteria are displayed and organized for a specific crew.

Table 4: Crew Performance Criteria for Crew 13230 in Lexington

Year	**$/ Emp**	**$/Hr**	**Accomp/ Emp**	**Accomp/ Hr**	**$/DWR**	**Accomp/ DWR**
2007	$201.75	$25.22	0.8	0.1	$807.00	3.1
2005	$81.82	$43.06	0.1	0.0	$180.00	0.2
2006	$59.60	$29.22	0.1	0.1	$119.20	0.2
2007	$49.02	$28.26	0.1	0.1	$124.00	0.2
2005	$53.00	$26.50	5.0	2.5	$106.00	10.0
2005	$51.50	$25.75	0.0	0.0	$103.00	0.0
2006	$63.33	$31.67	0.7	0.3	$190.00	2.0
2005	$180.75	$22.59	240.0	30.0	$723.00	960.0
2006	$173.14	$21.64	28.6	3.6	$1,212.00	200.0
2007	$137.67	$26.65	41.7	8.1	$826.00	250.0
2007	$87.67	$26.30	0.2	0.0	$263.00	0.5
Sum	**$1,139.25**	**$306.85**	**317.1**	**44.8**	**$4,653.20**	**1426.2**
Average	**$103.57**	**$27.90**	**28.8**	**4.1**	**$423.02**	**129.7**

Using these six performance criteria, the crews were ranked to identify the best-performing crews. Crews were ranked within each county, within each county category (urban, mixed, or rural) and overall. Tables 5-10 illustrate these rankings for each of the six performance criteria for 4 crews located in Bamberg County.

Table 5: Crews Ranked by Cost/Employee

			Rank by:		
County	**Crew #**	**Cost/Emp**	**County**	**Category**	**Overall**
Bamberg	70503	$230.01	3	7	49
Bamberg	70512	$262.45	4	9	57
Bamberg	70513	$174.30	2	6	31
Bamberg	70515	$162.42	1	3	21

Table 6: Crews Ranked by Cost/Hr

County	Crew #	Cost/Hr	Rank by:		
			County	**Category**	**Overall**
Bamberg	70503	$32.19	3	5	36
Bamberg	70512	$35.74	4	8	49
Bamberg	70513	$27.46	2	2	11
Bamberg	70515	$26.89	1	1	8

Table 7: Crews Ranked by Cost/Daily Work Report

County	Crew #	Cost/DWR	Rank by:		
			County	**Category**	**Overall**
Bamberg	70503	$1,731.29	3	8	56
Bamberg	70512	$2,257.99	4	9	59
Bamberg	70513	$1,214.48	2	7	46
Bamberg	70515	$925.83	1	4	33

Table 8: Crew Ranked by Accomplished/Employee

County	Crew #	Accomp/Emp	Rank by:		
			County	**Category**	**Overall**
Bamberg	70503	1060.6	2	2	4
Bamberg	70512	2625.8	1	1	1
Bamberg	70513	69.7	4	6	25
Bamberg	70515	202.0	3	4	12

Table 9: Crews Ranked by Accomplished/Hour

County	Crew #	Accomp/Hr	Rank by:		
			County	**Category**	**Overall**
Bamberg	70503	120.0	2	3	7
Bamberg	70512	302.6	1	1	3
Bamberg	70513	12.0	4	6	28
Bamberg	70515	27.9	3	5	15

Table 10: Crews Ranked by Accomplished/Daily Work Report

County	Crew #	Accomp/DWR	Rank by: County	Category	Overall
Bamberg	70503	5528.9	2	2	4
Bamberg	70512	11713.7	1	1	1
Bamberg	70513	487.5	4	6	20
Bamberg	70515	846.0	3	4	10

Based on these tables, it is evident that a crew may have varying levels of performance depending on which criteria are used in the analysis. For example, Bamberg county crew #70503 for cost-per-employee ranked 3rd in its county, 7th in its category, but 49th overall, whereas for the Accomp/DWR criteria it ranked 2nd it the county, 2nd in its category, and 4th overall. Bamberg crew #70512 ranked number one for its county, category and overall in both the Accomp/employee and Accomp/DWR criteria indicating that it could be one of the better-performing crews, but there is too much variability to make a reliable determination of performance.

To accommodate for the variation in individual crew performance across all criteria, a crew performance index (PIN) was devised. This index number is the average of the crew’s ranking in each of the performance areas when compared to every crew across the six counties (indicated by the “overall” column ranking). Using this ranking system, a lower index number denotes better crew performance. Table 11 illustrates an example of the ranking system using the crew performance index for the same four crews from Bamberg County that were examined above.

Table 11: Crews ranked by Performance Index Number

County	Crew #	Overall PIN	Rank
Bamberg	70503	26.0	17
Bamberg	70512	28.3	26
Bamberg	70513	26.8	20
Bamberg	70515	16.5	4

From this table, it is evident that Crew # 70512 performed well according to certain criteria, it ranked 26th overall, out of a total of 61 crews. As such, crew #70512 is a middle-tier crew rather than a top-performing crew. Bamberg County did have a top performing crew, Crew # 70515, which was ranked fourth overall.

Many maintenance crews in the SCDOT specialize in one specific type of major activity, such as mowing, signage or bridge repair. The performance criteria for these crews is more specific than for more-general crews and it can be reasonably expected that these crews would produce different performance results. Crews that were identified by specific type were grouped by specific activities and ranked based on the performance criteria described above. Table 12 illustrates these rankings based on activity type and the performance criteria, cost per hour.

Table 12: Driveway/Ditching Crews Ranked by Cost/Hr

Crew Type	County	Crew #	Cost/Hr	Rank
Driveway/ Patch/ Drainage/ Ditching	McCormick	23311	$35.62	15
		23312	$33.23	12
	Bamberg	70503	$32.19	11
		70512	$35.74	16
		70513	$27.46	2
	Lexington	13225	$30.61	5
		13240	$31.47	7
		13265	$29.00	4
		13275	$32.05	10
		13285	$33.48	13
	York	44611	$31.01	6
		44614	$31.77	8
		44617	$33.53	14
		44618	$32.01	9
	Richland	14055	$60.03	17
		14065	$281.79	18
		14080	$28.76	3
	Greenville	32316	$26.72	1

Table 13: Driveway Ditching Crews Ranked by Performance Index #

Crew Type	County	Crew #	PIN	Overall Rank
Driveway/ Patch/ Drainage/ Ditching	McCormick	23311	9.7	12
		23312	5.5	1
	Bamberg	70503	8.5	5
		70512	9.0	8
		70513	9.0	8
	Lexington	13225	9.5	11
		13240	14.3	18
		13265	8.5	5
		13275	8.0	4
		13285	10.2	13
	York	44611	13.5	17
		44614	8.5	5
		44617	9.3	10
		44618	12.3	16
	Richland	14055	12.0	15
		14065	11.7	14
		14080	6.0	3
	Greenville	32316	5.5	1

Table 13 illustrates a ranking of the crews based on the activity type, but in this analysis, the performance index is used as the performance criterion. This information was used to generate a list of the Top 5 and Bottom 5 performing crews for the representative counties as shown in Tables 14 and 15.

Table 14: Top 5 Crews

Rank	**County**	**Crew #**	**Type**	**# Crew Members**
1	Richland	14015	Sign/Pavement	11
2	York	44616	Bridge Maintenance	5
3	Greenville	32316	Drainage	6
4	Bamberg	70515	Mowing/Complaints	7
5	McCormick	23312	Drain/Drive/Patch	6

Table 15: Bottom 5 Crews

Rank	**County**	**Crew #**	**Type**	**# Crew Members**
57	Richland	14060	Asphalt	5
58	Richland	14070	Bridge	6
59	York	44611	Patch/Litter	7
60	Lexington	13240	Full Depth Patching	7
61	Richland	14035	General	8

Tables 16 and 17 detail the composition of the Top 5 crews and the Bottom 5 crews, respectively. The description of the crew represents the primary activity that the crew performs on a regular basis. Each crew member has an associated title ranging from Trade Specialist II to Trade Specialist V with a corresponding level from 2A to 5C. The lower levels typically represent workers with less experience in his/her position while higher levels, 4 or 5, usually represent foremen or supervisor-level workers.

Table 16: Composition of Top 5 Crews

Description	Level	# in Crew
14015 Richland - Sign/Pavement		
TRADE SPECIALIST II	2A	1
TRADE SPECIALIST II	2B	5
TRADE SPECIALIST II	2C	1
TRADE SPECIALIST II	2D	1
TRADE SPECIALIST III	3A	2
TRADE SPECIALIST IV	4B	1
44616 York - Bridge Maintenance		
TRADE SPECIALIST II	2B	1
TRADE SPECIALIST II	2D	1
TRADE SPECIALIST III	3A	1
TRADE SPECIALIST III	3B	1
TRADE SPECIALIST IV	4C	1
32316 Greenville - Drainage		
TRADE SPECIALIST II	2A	1
TRADE SPECIALIST II	2B	1
TRADE SPECIALIST II	2C	1
TRADE SPECIALIST II	2D	1
TRADE SPECIALIST III	3B	1
TRADE SPECIALIST IV	4A	1
70515 Bamberg - Mowing/Complaints		
TRADE SPECIALIST II	2A	1
TRADE SPECIALIST II	2B	4
TRADE SPECIALIST II	2D	1
TRADE SPECIALIST IV	4B	1
23312 McCormick - Drain/Drive/Patch		
TRADE SPECIALIST II	2B	2
TRADE SPECIALIST II	2C	1
TRADE SPECIALIST II	2D	1
TRADE SPECIALIST III	3B	1
TRADE SPECIALIST IV	4A	1

Table 17: Composition of Bottom 5 Crews

Description	Level	# in Crew
14060 Richland – Asphalt		
TRADE SPECIALIST II	2D	1
TRADE SPECIALIST III	3A	3
TRADE SPECIALIST IV	4B	1
14070 Richland – Bridge		
TRADE SPECIALIST II	2A	1
TRADE SPECIALIST II	2B	1
TRADE SPECIALIST II	2D	1
TRADE SPECIALIST III	3A	2
TRADE SPECIALIST IV	4C	1
44611 York - Patch/Litter		
TRADE SPECIALIST II	2C	2
TRADE SPECIALIST II	2D	3
TRADE SPECIALIST III	3B	1
TRADE SPECIALIST IV	4C	1
13240 Lexington - Full Depth Patching		
TRADE SPECIALIST II	2B	3
TRADE SPECIALIST II	2D	1
TRADE SPECIALIST III	3A	2
TRADE SPECIALIST IV	4B	1
14035 Richland - General		
TRADE SPECIALIST II	2B	1
TRADE SPECIALIST II	2C	2
TRADE SPECIALIST II	2D	1
TRADE SPECIALIST III	3A	3
TRADE SPECIALIST IV	4B	1

The first analysis, while demonstrating which crews were performing at the highest levels in different categories, could not provide complete insight in terms of the research objectives. The data was too segmented to provide an overall outlook on the performance of the crews. No data trends were readily visible across the different performance categories. In addition, data entered into the HMMS system involved different units of measure, making comparisons across multiple categories impractical. This analysis provides valuable data for the SCDOT in terms of performance measurements and evaluations of maintenance crews; however, it would be necessary to examine a different measure of analysis in order to properly determine optimum crew configurations.

Activity Composite Score

The initial analysis was presented to the SCDOT for review and based upon the outcome, it was determined that analyzing the data according to work descriptions would produce more accurate results. This will result in a more usable comparison of data. As a foreman enters data into HMMS, it is classified in two different ways. First, the data is coded by an activity description. This is a broad representation of the work entered into the system, each of which includes different work descriptions, which provides additional detail about the work. For example, the activity description of surface repairs could involve the work description of pothole patching by hand. This method of data organization and analysis will allow for comparisons to be made with uniform units of accomplishment and thus, for each work description, an optimal crew composition for each county type may become more evident. This should enable the SCDOT to develop more precise recommendations for crew size based upon the type of work at hand. Table 18 illustrates the work description rankings for the construction of outfalls in the rural counties of Bamberg and McCormick.

Table 18: Rural Crew Analysis for Construction of Outfall

Crew #	Rank	Year	Equip Cost	Labor Cost	Accomp Qty	Total DWR	Total Emp	Total Hrs	Cost/ Unit
70513	2	2005	$757	$1,008	$935	1.0	7	56.0	$1.89
		2006	$461	$1,487	$500	2.0	11	88.0	$3.90
		Avg	$609	$1,248	$717	1.5	9	72.0	**$2.59**
70515	1	2007	$140	$157	$1,500	1.0	1	8.0	$0.20
		Avg	$140	$157	$1,500	1.0	1	8.0	**$0.20**
23312	3	2006	$106	$332	$30	1.0	4	16.0	$18.07
		2007	$53	$263	$100	1.0	4	12.0	$3.16
		Avg	$80	$298	$65	1.0	4	14.0	**$6.60**

Most crews have the years 2005, 2006 and 2007 listed since these were the three years for which data was gathered. However, certain crews did not have data for a given fiscal year, and in some cases, a portion of the data was incomplete and was thus discarded. The table shows the costs incurred by the crew for labor, equipment, and materials for a given fiscal year. The accomplished quantity describes the amount of work that was completed by the crew for the entire fiscal year. The units of this column changed with different work descriptions. However, the benefit of comparing crews and performance by work description is that the units for work accomplished remain the same. The final column is the cost-per-unit column by which the crews were analyzed. For each crew, the bold number in the cost-per-unit accomplished column indicates the average cost-per-unit accomplished for all the data gathered. This number was computed by taking the sum of all costs incurred by a crew for the work description, and dividing it by the sum of the units accomplished by the crew. This bold number is the primary criterion by which a crew's performance was analyzed for each type of work description it performed. All crews are ranked according to this criterion. A sample of these rankings for driveway installations is shown in Table 19.

Table 19: Urban Crews Ranked by Cost/Unit Accomplished for Driveways

Organization	**Crew #**	**Cost/Unit**	**Rank**
DRAINAGE	32316	$549.50	1
PLEASANT HILL SHED	32314	$556.48	2
GREENVILLE	32311	$689.40	3
4020 SECTION	14020	$699.83	4
4030 SECTION	14030	$748.79	5
FORK SHOALS SHED	32315	$759.59	6
N GREEN SHED 1	32312	$771.67	7
4025 SECTION	14025	$774.56	8
BALLENTINE SHED	14040	$786.17	9
N GREEN SHED 2	32313	$787.89	10
NORTH AREA DITCH	14065	$849.13	11
EASTOVER SHED	14035	$873.66	12
4050 SECTION	14050	$877.95	13
SIMPSONVILLE SHED	32331	$937.50	14
SOUTH AREA DITCH	14080	$1,737.00	15

The cost-per-unit accomplished and a crew's corresponding rank for the given work description is shown. Organizing the data in this manner allowed the SCDOT to identify the top-performing crews for each work description in each type of county.

When organized by work description, the data yields many different crews performing at the top of their county classification. A broader performance criterion was needed to evaluate these crews based on the cost-per-unit accomplished. A composite index number, or Activity Composite Score, was developed, rating each crew's performance within a given activity description. Once these composite scores were generated, analyzing the crew size of the top-performing crews pointed to optimum crew configurations for different activities. Table 20 illustrates how this data was compiled for

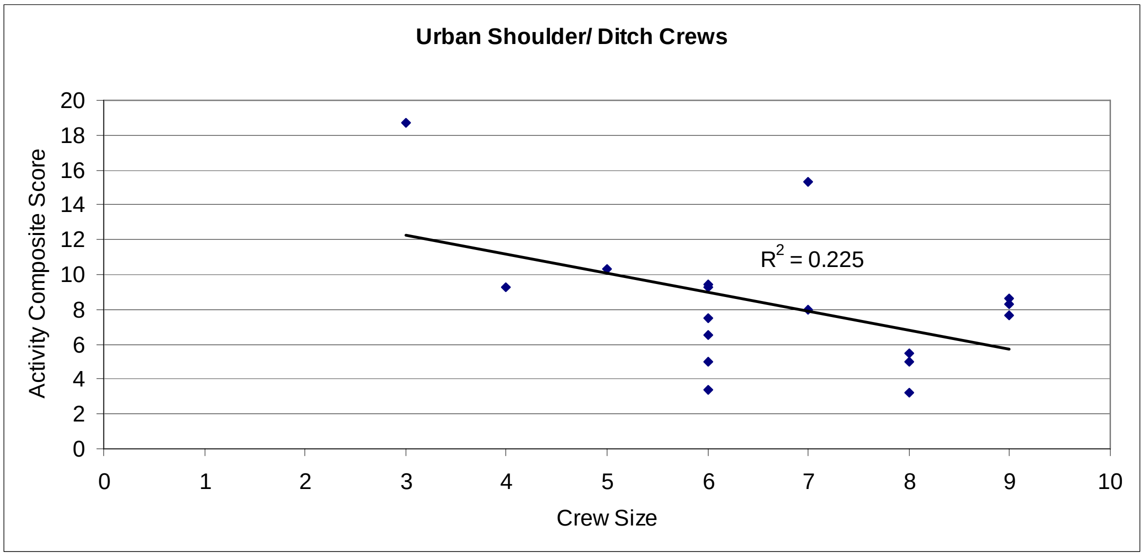
Shoulders and Ditches in the Mixed Counties category. All of the Composite Rankings can be found in Appendices C-E.

Table 20: Composite Index Rankings for Shoulders & Ditches in Mixed Counties

Crew	**Description**	**Workers**	**Work Description. Ranks**	**Activity Composite Score**	**Rank**
13250	INTERSTATE	6	2,2,2,3,1	2	1
13250	PELION DITCHING	6	3,7,1,1	3	2
13270	PELION MOW/PATCH	6	4,8,2	4.7	3
44614	DITCHES & SHOULDERS	7	13,5,3,3,4	5.6	4
13285	DITCHING	8	16,2,2,3	5.75	5
13275	PELION DRAINAGE	8	11,1,5,4,8,6,7	6	6
44612	EAST ROCK HILL	6	8,7,4,9,5	6.6	7
13290	BATESBURG/LEESVILLE	9	3,3,6,6,11,12	6.8	8
44620	I77 SPECIAL PROJS	7	9,10,5,5,6	7	9
13242	CONCRETE	5	6,3,4,12,10,13	8	10
13225	DRAINAGE	7	10,5,9,9,13	9.2	11
44613	FORT MILL/TEGA CAY	6	1,14,15,7,10	9.4	12
13265	W/COLA DRAINAGE	7	7,4,15,11,15	10.4	13
13220	MOW/PATCH	10	15,2,17	11.3	14
44617	DRIVEWAYS/REQUESTS	7	17,13,13,8,9	12	15
13260	W/COLA MOW/PATCH	5	16,12,8	12	16
44618	WEST ROCK HILL	4	18,11,12,10,14	13	17
44618	ROCKHILL-DRIVEWAYS	7	12,16,14,14,16	14.4	18
13240	FULL DEPTH PATCHING	7	14,18,17,11	15	19

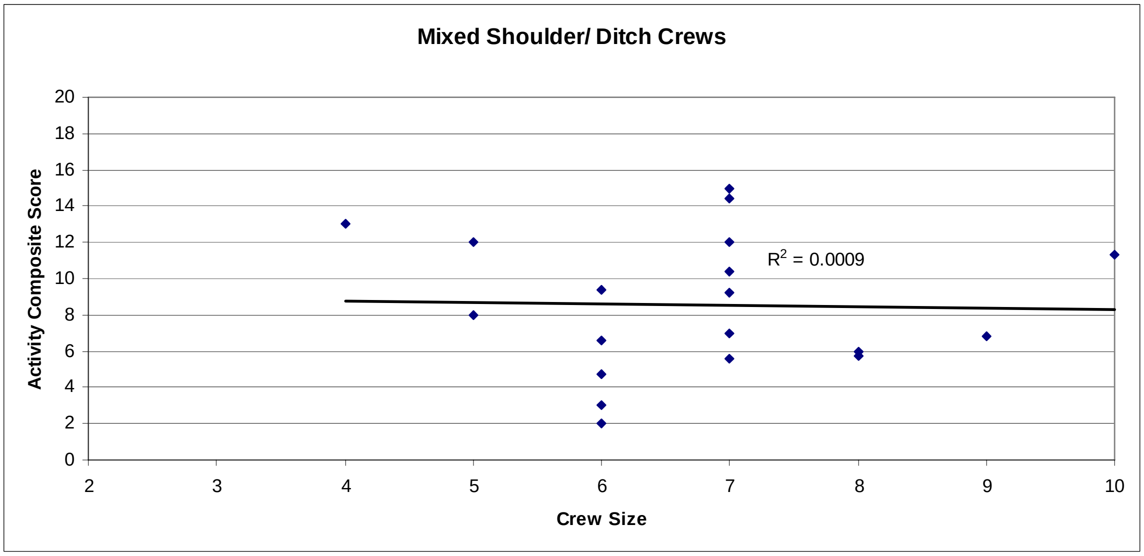
The work description column lists the ranks based upon the cost-unit-accomplished for each crew. The multiple rankings are for the different work descriptions that all correspond to a single activity. These are averaged to develop the Activity Composite Score used in the final ranking of the crews. The lower the composite number, the higher the crew was ranked. Once the ACS was determined for each of the crews, an analysis thereof indicates optimum crew configurations. It is anticipated that better-performing crews within activity type and county category will have similar crew configurations. Figures 1 through 7 reflect the plots of each crew's size versus its composite score (ACS).

Figure 2: Crew Size and ACS for Urban Shoulder and Ditch Crews



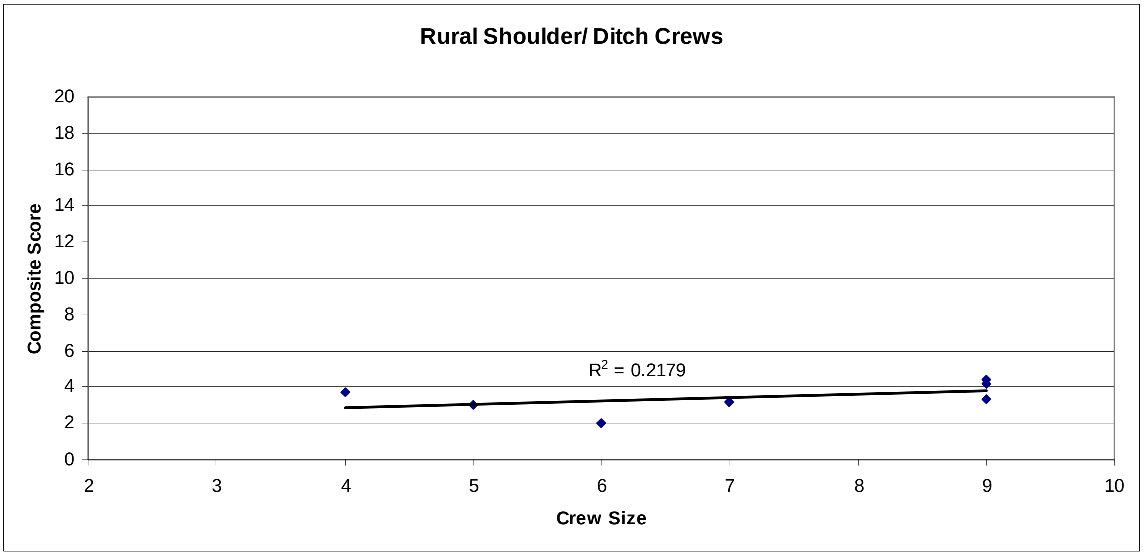
From this plot it is evident that there is a significant variation in crew size for shoulder and ditch activity in the urban counties. However, the best performing crews had either six or eight crew members. While this is not a conclusive determination, it does indicate that crews of that size in urban counties are most able to perform their jobs productively. It should be noted that there was insufficient data to produce a statistically significant regression analysis. There is therefore no evidence to support the hypothesis that a crew's size can determine its performance, which is confirmed by an R^2 value of 0.225.

Figure3: Crew Size and ACS for Mixed Shoulder and Ditch Crews



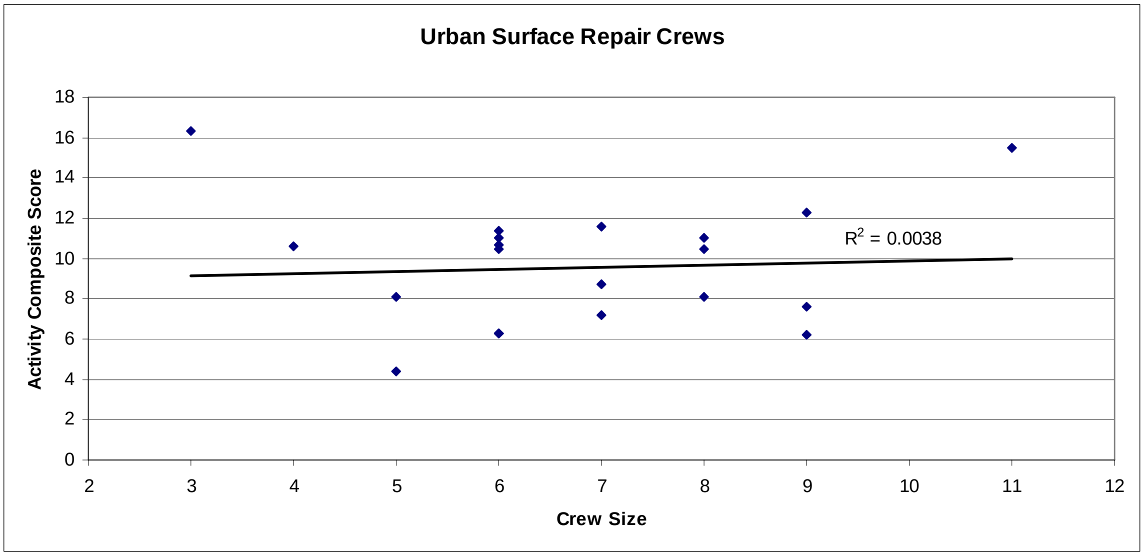
It once again becomes apparent that the better-performing crews tended to have only six crew members, although there was still a wide range of performance for this number of crew members. The sample size is still too small for a valid statistical comparison. The fact that these counties include urban areas, as well as suburban and rural areas, may also contribute to the variation in the performance scores. The varying degrees of traffic congestion, population densities and changes in road conditions may make a uniform analysis more difficult.

Figure 4: Crew Size and ACS for Rural Should and Ditch Crews



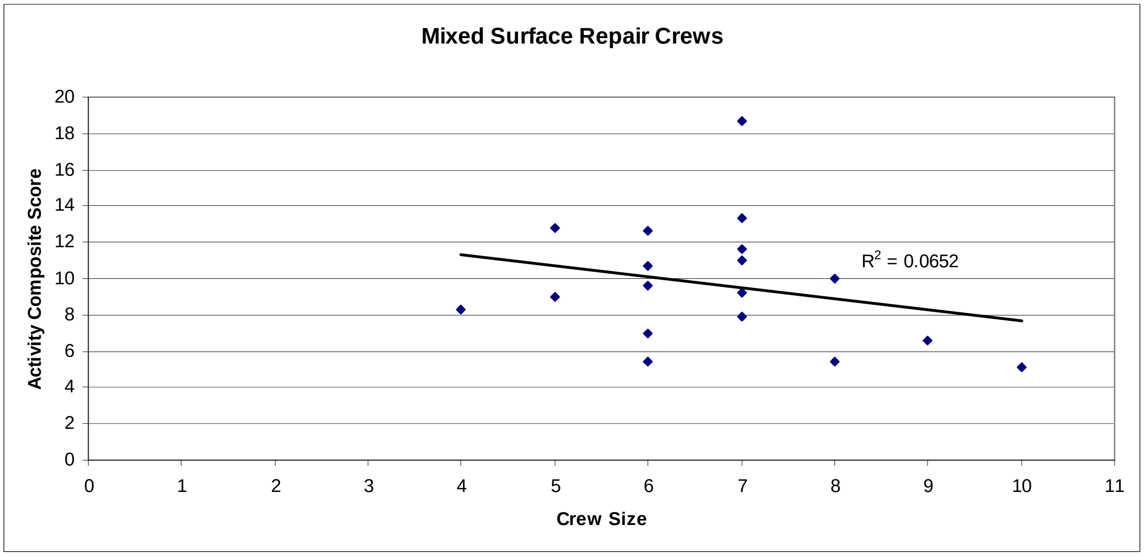
Rural crews appear to perform at similar levels regardless of crew size. There are many reasons why performance may be less correlated to crew size in rural crews than for crews in a more urban setting. One factor may be reduced traffic congestion allowing for work to be completed at a more rapid pace. Perhaps these crews have a higher degree of cohesion and camaraderie due to the smaller county office size. While speculation may produce some interesting hypotheses, further research into rural crews, and how they operate differently than urban crews, would be necessary to prove or disprove any such theory.

Figure 5: Crew Size and ACS for Urban Surface Repair Crews



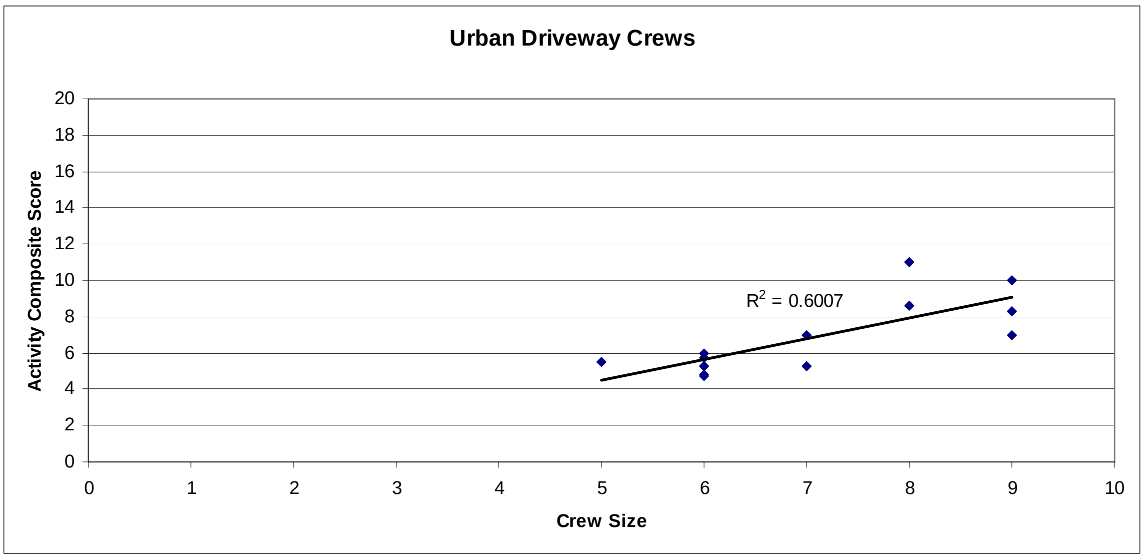
For this activity there is too much variability to determine an optimum crew size. The best-performing crew only had five members, but crews with six, seven, and nine members all performed similarly well. This may indicate that in urban counties the variation in types of surface repairs may warrant variations in crew sizes as well.

Figure 6: Crew Size and ACS for Mixed Surface Repair Crews



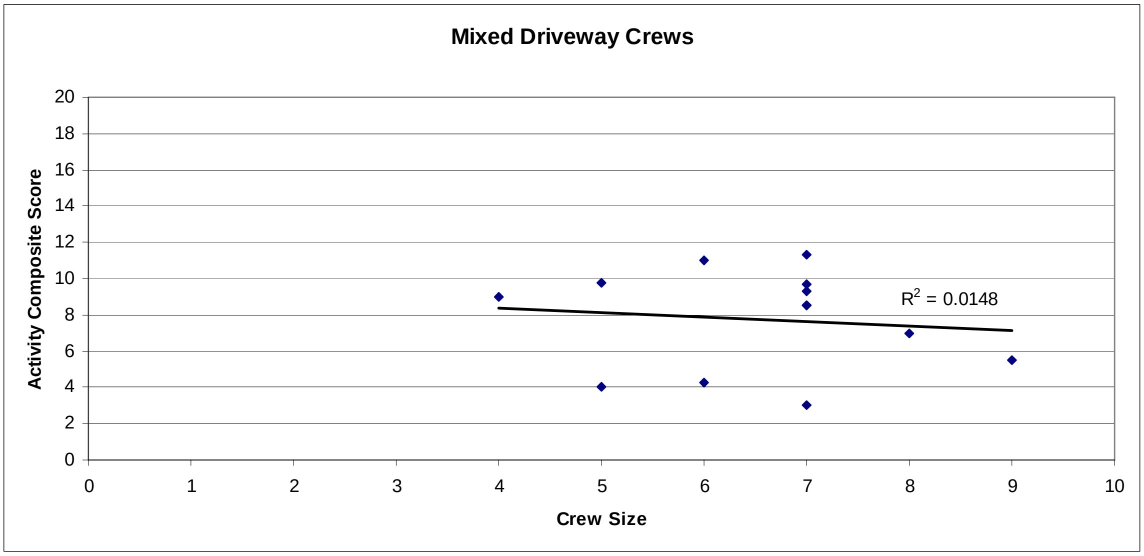
There is not as much variation in the data for the mixed counties, but the range of crew sizes is still fairly large, with similarly performing crews of six, eight, and ten. Again, further analysis of the crews may be warranted. The data set for the rural counties only included five crews, which is much too small a sample for a insightful comparison and can not be analyzed by this method.

Figure 7: Crew Size and ACS for Urban Driveway Crews



In the area of driveway work, the highest-performing crews in urban areas were composed of six or seven members. The performance of crews with eight and nine members is not as productive.

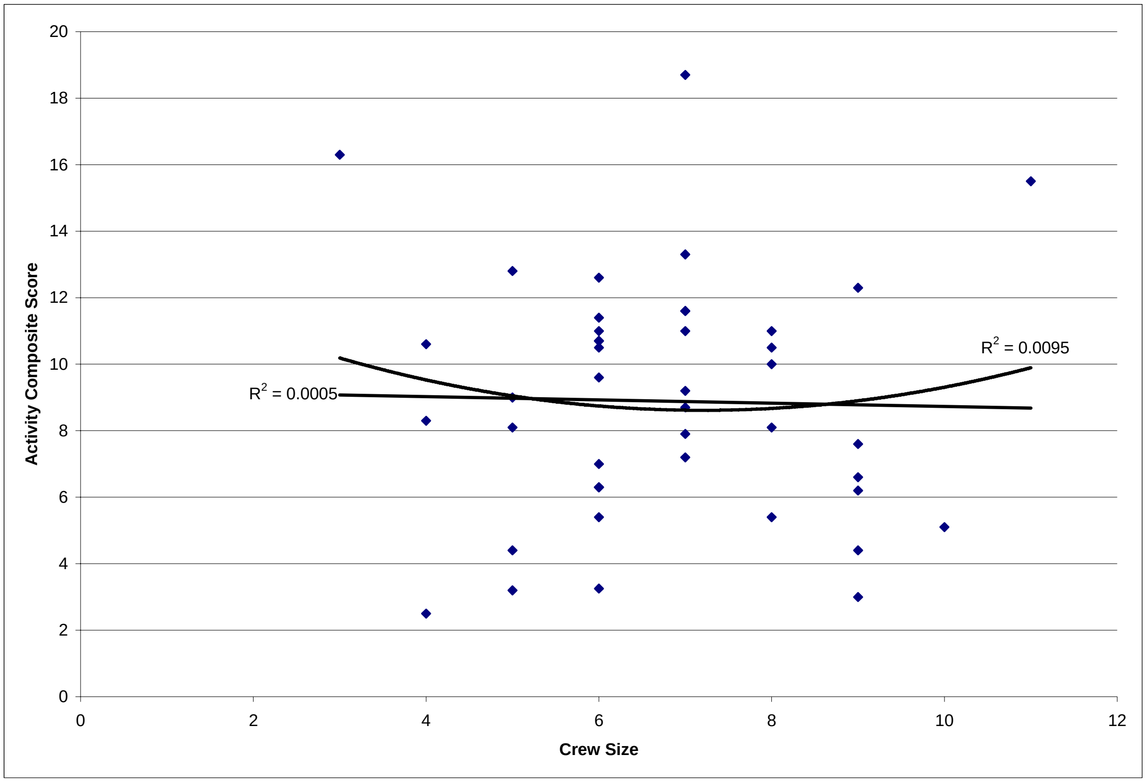
Figure 8: Crew Size and ACS for Mixed Driveway Crews



As before, there is significant variation in performance of driveway crews in the mixed counties. The best-performing crews had five, six, or seven members. The data set is small and would benefit from the addition of more data to determine a better recommendation of crew size. The data for the rural counties includes only five data points and is thus too small for even a basic analysis, and will not be included in this report.

Using the data available through HMMS and the performance criteria, a statistically significant determination of optimum crew sizes was not possible. However, a basic review of the data begins to suggest that certain activities in certain county types may have associated crew sizes that would lead to increased productivity and better crew performance. There may be other reasons for why these particular crew sizes were used for these activities, such as equipment or safety requirements, the preference of the resident maintenance engineer, the availability of workers in an area, or the experience level of the workers involved. It is recommended that additional analysis of the better-performing crews identified in this research be conducted to determine the specific characteristics thereof, and if they in fact represent an optimal crew configuration.

Figure 9: Crew Size and ACS for all Crews



This chart reaffirms the notion that there is a significant amount of variation in performance for all size crews. Neither the linear or polynomial trend lines have an r-value high enough to be of any significance. The upward slope of the polynomial line does suggest that with more data, the possibility of the best-performing crews having either more or less members does exist. However, from the data available, there is no statistical evidence to accept this hypothesis.

Equipment Optimization

The allocation and utilization of equipment for SCDOT maintenance crews can have a tremendous impact on the productivity and performance of crews. The equipment used by each crew is recorded and entered into HMMS for a work description. The equipment choice has a profound effect on the performance of a crew. Examining the equipment usage according to work description and identifying the most-used pieces will allow for the SCDOT to adjust its equipment usage and future recommendations for optimal performance from their crews.

For each work description, a crew has a certain number of units of equipment available for use on a given activity. Those units are determined by equipment standards or specifications set for different activities at the state level. However, certain types of equipment are used at a much higher rate than others for a given assignment. Analyzing the utilization of equipment and eliminating any unnecessary or redundant equipment should allow districts to save money and reduce wasted resources.

Many factors influence the type of equipment chosen by a crew, including work conditions, the desire by a particular crew to hoard equipment, the quality of equipment, and equipment utilization rates. Equipment utilization rates determine the minimum amount of usage that a piece of equipment must receive annually in order to be replaced. Certain units of equipment achieve their utilization rate in short order while others do not. As a result, SCDOT engineers and crews often make decisions on equipment selection based on current equipment utilization rates. Certain pieces of equipment may not be well-suited for a particular job, but may be selected simply to achieve utilization rates.

Equipment utilization for each work description was analyzed to determine the optimum use of equipment resources. Table 21 shows the actual equipment usage reported by crews for minor leveling with a machine. Table 22 reflects the optimized equipment usage for the same crews.

Table 21: Equipment Usage by Rural Crews for Minor Leveling with Machine

Year	Equip #	Description	Cost	Hours	Total DWRs
2005	009-03-0277	TRUCK, 3/4 T UTIL (STD)	$1,316	12.00	2
	011-03-0305	TRUCK1.5 T PLTFM STD	$1,316	12.00	2
	013-03-0617	TRUCK, 5 CY DUMP (3P)	$927	8.00	1
	013-03-0683	TRUCK, 5 CY DUMP (2P)	$389	4.00	1
	014-01-0016	TRUCK, 8 CY DUMP (3P)	$1,316	12.00	2
	014-01-0151	TRUCK, 8 CY DUMP (2P)	$927	8.00	1
	099-01-0116	GRADER, MOTOR, >25000 LBS	$1,316	12.00	2
	109-02-0178	KETTLE, ASPHALT	$1,316	12.00	2
	171-04-0036	ROLLER, TANDM SEL-PR 4-6T	$1,316	12.00	2
2006	009-03-0277	TRUCK, 3/4 T UTIL (STD)	$1,115	34.00	4
	011-03-0305	TRUCK1.5 T PLTFM STD	$1,115	34.00	4
	013-03-0617	TRUCK, 5 CY DUMP (3P)	$207	8.00	1
	014-01-0016	TRUCK, 8 CY DUMP (3P)	$908	26.00	3
	014-01-0151	TRUCK, 8 CY DUMP (2P)	$908	26.00	3
	099-01-0116	GRADER, MOTOR, >25000 LBS	$1,115	31.00	4
	109-09-0012	KETTLE, ASPHALT	$811	26.00	3
	171-04-0036	ROLLER, TANDM SEL-PR 4-6T	$1,115	34.00	4
	203-04-0031	BACKHOE/LOADER, 2WD MED	$304	8.00	1

Table 22: Optimized Equipment Usage by Rural Crews for Minor Leveling with Machine

Equip #	Description	Cost	Hours
009-03-0277	TRUCK, 3/4 T UTIL (STD)	$1,115	34.00
011-03-0305	TRUCK1.5 T PLTFM STD	$1,115	34.00
014-01-0016	TRUCK, 8 CY DUMP (3P)	$908	26.00
014-01-0151	TRUCK, 8 CY DUMP (2P)	$908	26.00
099-01-0116	GRADER, MOTOR, >25000 LBS	$1,115	31.00
109-09-0012	KETTLE, ASPHALT	$811	26.00
171-04-0036	ROLLER, TANDM SEL-PR 4-6T	$1,115	34.00

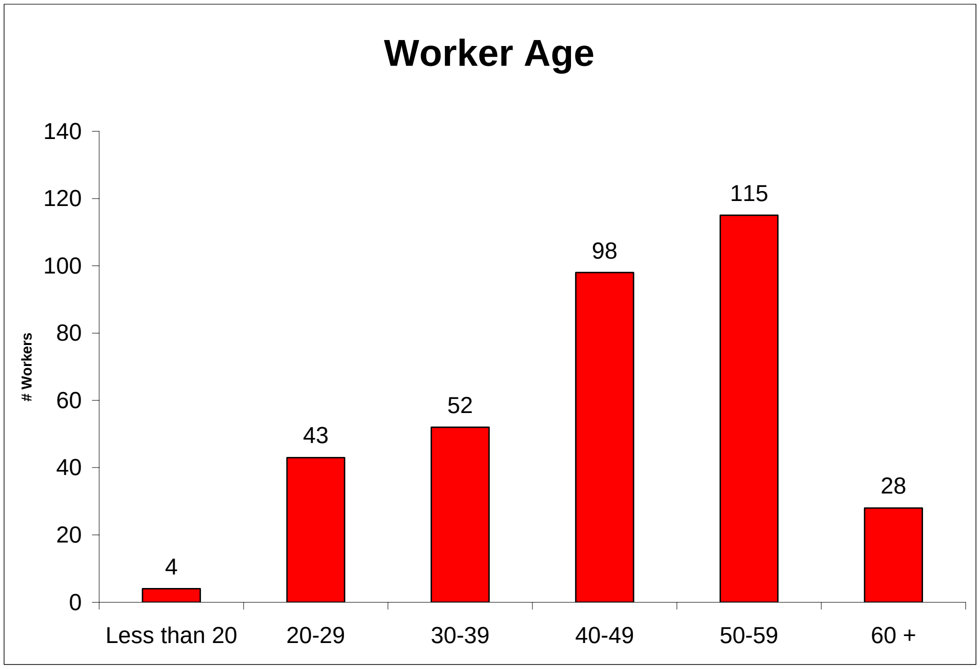
These two tables show the equipment usage of the crews in the rural counties of Bamberg and McCormick for the work description minor leveling with a machine. The tables show the equipment costs, the number of hours the equipment was used and the amount of DWRs filed involving each piece of equipment. Based on discussions with SCDOT, it was determined that if any piece of equipment is used less than 50% of the time it can be deemed unnecessary. For instance, for the given activity the three quarter ton utility truck (Equip # 009-03-0277) was reported in four DWRs for fiscal year 2006. Both the 5 CY dump truck (Equip # 013-03-0617) and the backhoe (Equip # 203-04-0031) were only used once DWR which is less than the 2 DWRs that would represent 50% of the usage by the utility truck. These pieces of equipment were not used enough to warrant being recommended for these types of activities – either other pieces of equipment will work as well, or necessary equipment could be borrowed from other activities as needed. The optimized equipment lists can be used by the SCDOT to further refine their equipment recommendations and utilization rates which will in turn boost crew performance from more efficient equipment usage

In addition to quantitative data collected, interviews of SCDOT maintenance employees provided an insightful supplement to the data as well as anecdotal suggestions for improvements. While many different suggestions were voiced, there was one issue that was raised repeatedly: equipment utilization. Many units of equipment are used often, thus making the required usage rate easy to attain. There are however, many units of equipment that are so infrequently needed it is difficult to attain the required usage. Equipment is often assigned based on equipment utilization numbers, which may not accurately reflect the equipment needed or preferred by the crews. The maintenance crews then become frustrated with using equipment that may not be designed for the work only to increase the utilization rate for that unit. While the research team recognizes the need and importance of equipment utilization rates, it would be beneficial for the SCDOT to perhaps internally investigate viable alternatives to mandated equipment utilization rates or update these rates based on input from the maintenance workforce for each activity and county type.

Workforce Survey Analysis

The SCDOT workforce survey was developed and administered in an attempt to gather more information about individual maintenance employees, as well as to analyze the opinions of the crews on several items of importance to the SCDOT. A copy of the survey can be found in Appendix A. The average age of the SCDOT maintenance worker is 43 and Figure 8 shows the age range of these workers.

Figure 10: SCDOT Worker Age



Almost 10% of the workforce is female, which is higher than the construction workforce, which generally tends to have about 2% of production occupations held by women. The majority of the SCDOT workforce is educated. Over 78% of the workers interviewed hold at least a high school diploma and almost 29% have some college or a college degree.

Of particular importance to the current research project were several questions concerning the performance objectives set by the SCDOT, and whether they were clearly understood by each crew's foreman. Question 14 from the survey asked: "Are performance targets set for your crew?" Of the 56 foreman respondents, 93% indicated that they were aware of the performance targets for their crew. This means that only 7% of foremen were not educated as to their crew's performance targets.

Another question, Question 15, followed up by asking, "Do you know what these targets are?" Over 87% (49 out of the 56 foremen) indicated that they were indeed knowledgeable of these targets. Also, 84% agreed that the targets are realistic. However, when asked if he/she was concerned with reaching these targets, only 68% of the foremen surveyed responded affirmatively. There are a number of potential reasons for this answer. The foremen may believe that the targets are realistic and there is little concern about the crew's ability to meet them. Conversely, it could indicate a lack of motivation for achieving or exceeding the performance standards. The SCDOT may wish to consider incentivizing performance achievement. Performance-based incentive packages are common and accepted and have proven beneficial in many different types of workforces. Specifically this technique has been shown to be effective by the NCDOT (Aschbrenner, D.R., Domico, D. and Fountain, A.M.; 2000).

This research has focused on the development of optimal crew configurations which is primarily dependent on the size of the crew. Two questions in the survey asked the maintenance workforce about the size of their crews. Of the 382 respondents, almost 64% felt as if their crew was too small and would benefit from additional members. Only 10 people (2.6%) answered that their crew was too big. From the data, it is difficult to relate crew size to performance, but there seems to be an opinion among the maintenance workers that crew size is an item of concern and may need to be increased in certain instances. This request for additional workers will have to be reviewed on a case by case basis, as the ACS data suggests that additional workers may not necessarily result in an increase of crew productivity.

The teamwork of crews is important and the cohesiveness of certain crews, especially in rural settings where the crews may have longer tenure together, can significantly improve productivity. The workers surveyed were asked to rank how well they get along as a crew on a scale of 1 to 10 with 1 being poor and 10 being excellent. Table 23 summarizes the responses.

Table 23: Respondents' Rating of How Well Crewmembers Get Along

	# Respondents	**%**
Poor (1-3)	15	4.2
Average (4-6)	47	13.1
Good (7-8)	98	27.2
Excellent (9-10)	200	55.6

Survey data shows that 83% of crews get along at least good with one another, if not excellent. This is encouraging as it is cited in the literature review that satisfaction at the workplace will lead to increased worker productivity Howell, Gregory A., Oglesby, Clarkson H. and Parker, Henry W; 1989).

Another way to manipulate the data from the workforce survey analysis is to identify the top and bottom crews in each of the different classifications of counties and compare their crewmember responses. Figure 11 and Figure 12 illustrate this comparison for the response to question number 39 of the survey: "I am provided with the proper equipment I need to best perform my job." The data analyzed in these figures is taken from the top 5 crews in each county classification and the bottom 5 crews in each county classification.

Figure 11: Top Crews Survey Question # 39: Proper Equipment Provided?

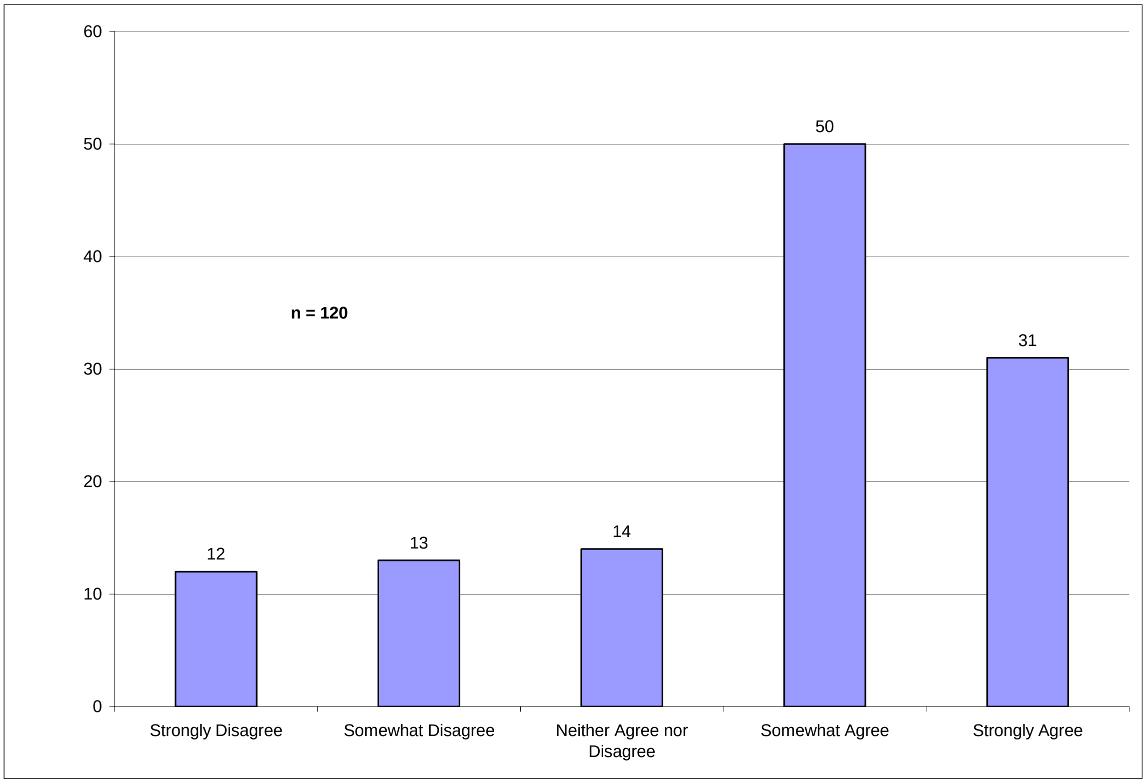
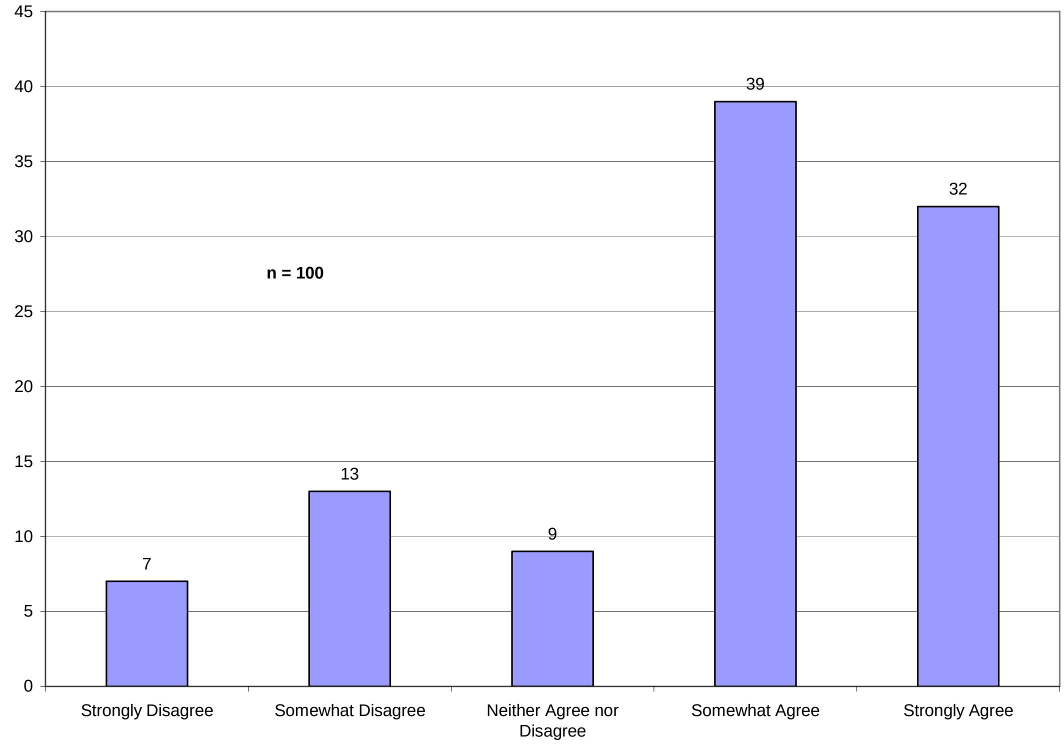


Figure 12: Bottom Crews Survey Question #39: Proper Equipment Provided?



For the top-performing crews, 68% of respondents somewhat agree or strongly agree that the proper equipment is being provided for them to perform their jobs properly. This number was even greater for the bottom performing crews at 71%. These tables show that in the eyes of the workforce they are being provided, in the majority of cases, with the proper equipment. This is of particular importance since, according to the recent Construction Industry Institute research, the most-influential factor impacting labor crew productivity today is a lack of resources available to workers (CII, 2001).

Figure 13: Top Performing Crews Years of Service with SCDOT

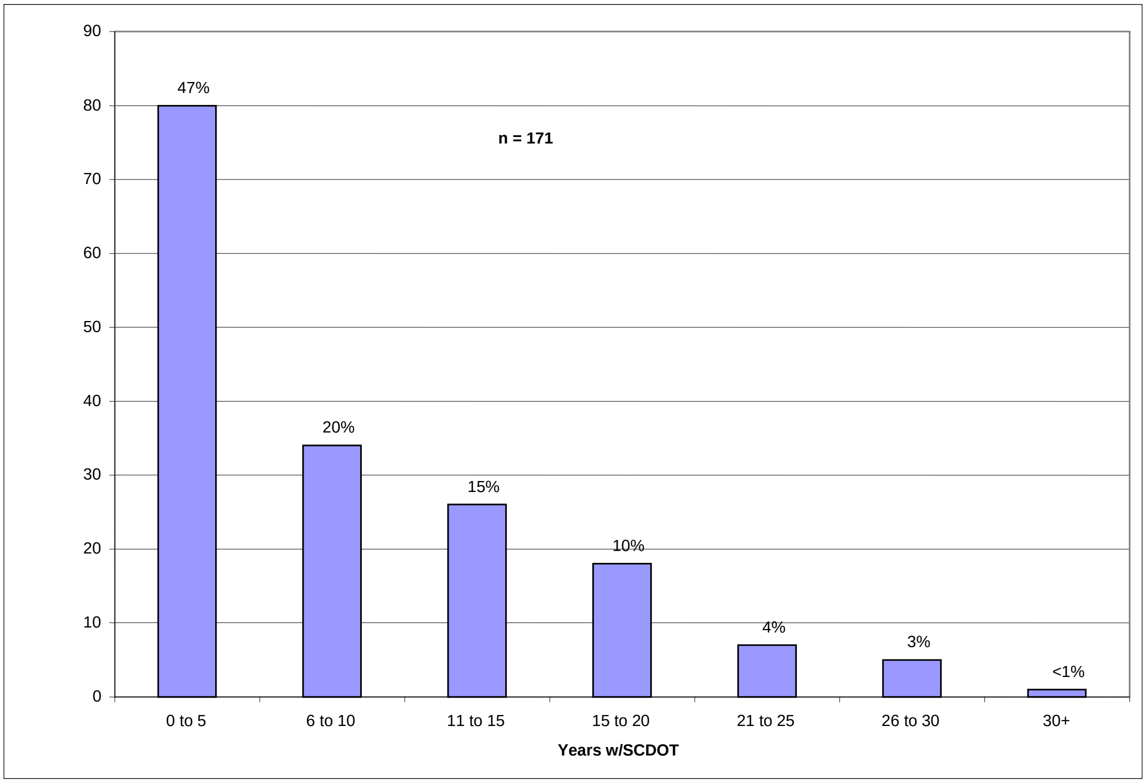
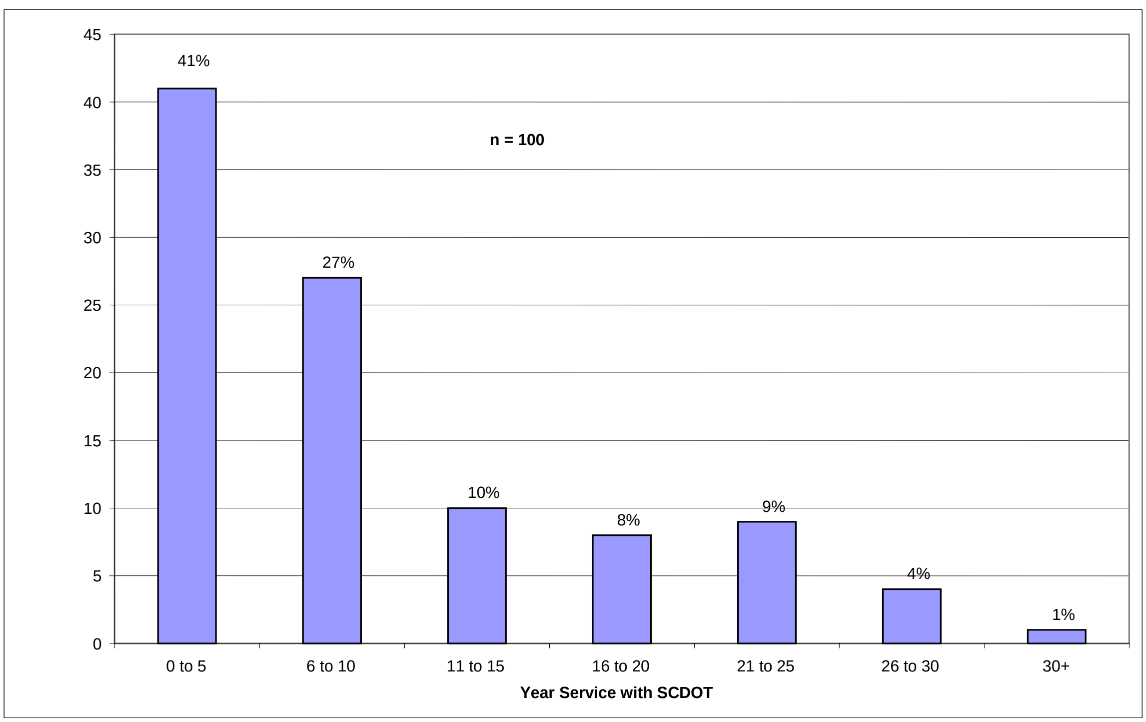


Figure 14: Bottom Performing Crews Years of Service with SCDOT



Figures 13 and 14 show that the majority of the workers for both the top and bottom performing crews have less than six years service with the SCDOT. This is 47% and 41% of the workers in these crews respectively. To assume that workers with less experience are generally younger than those with more experience would suggest that age of crew workers has little effect on performance. However, figures 15 and 16 suggest that age of crew members may have a significant effect on crew performance.

Figure 15: Top Crews Worker Age

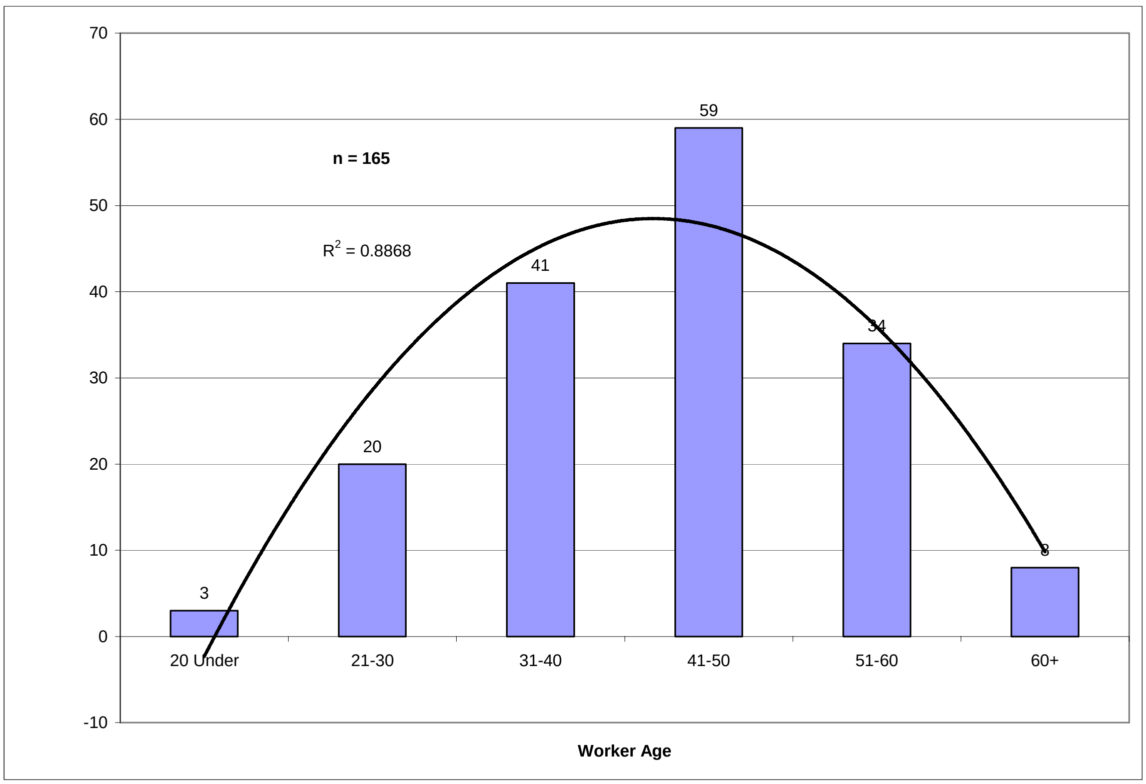
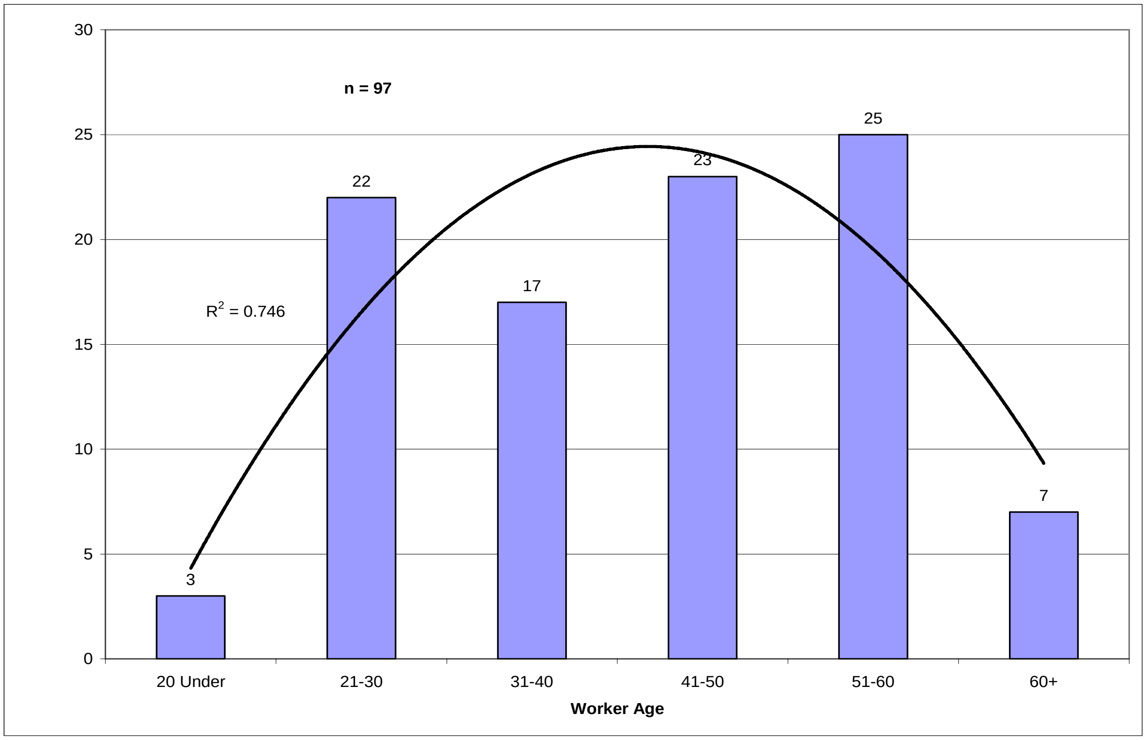


Figure 16: Bottom Crews Worker Age



The top crews follow a normal distribution with a high r-value of 0.89. The data for the bottom crews follows a normal distribution as well, but data is more spread out with a lower r-value of 0.74. The top-performing crews are mostly composed of workers between the age of 40 and 50, which is often considered one of the most skilled age ranges due to experience level and the fact that the body has not begun to deteriorate to where it impedes the ability of the person to work effectively. The lower-performing crews had roughly equal numbers of people in the age brackets, indicating that there may not be a sufficient balance between the number of younger (i.e. less experienced) crew members and the older ones.

Figure 17: Top Crews Comfort with Technology

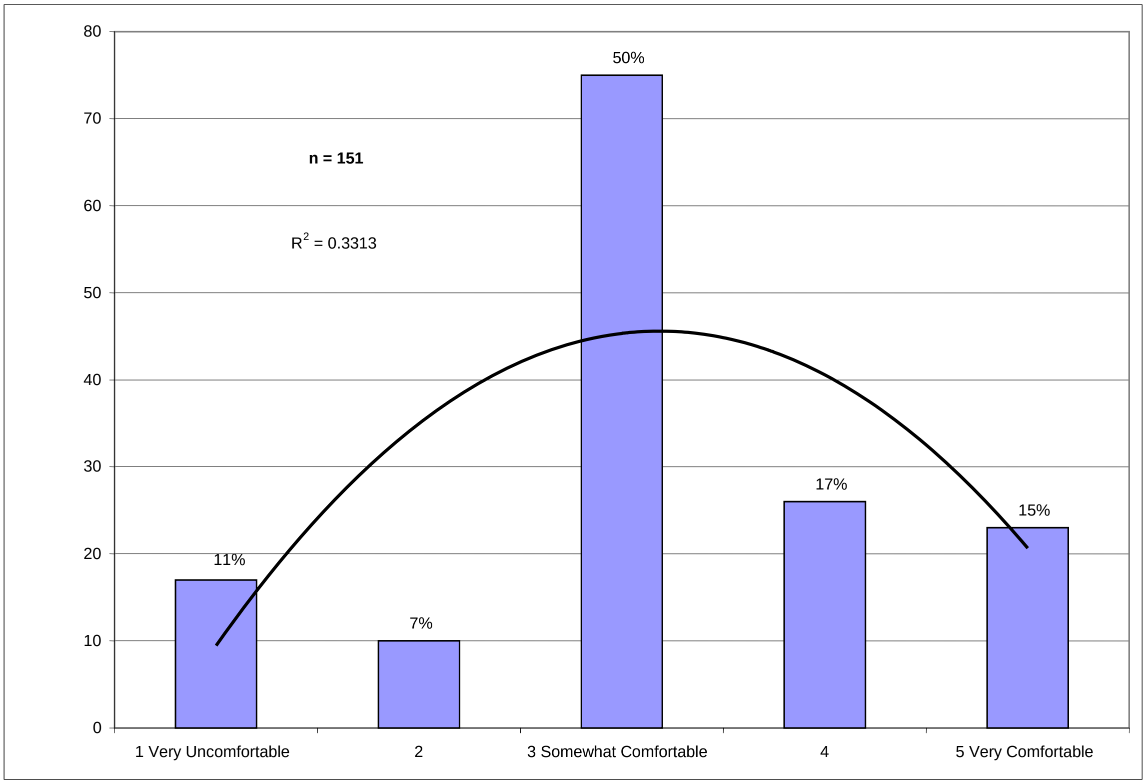
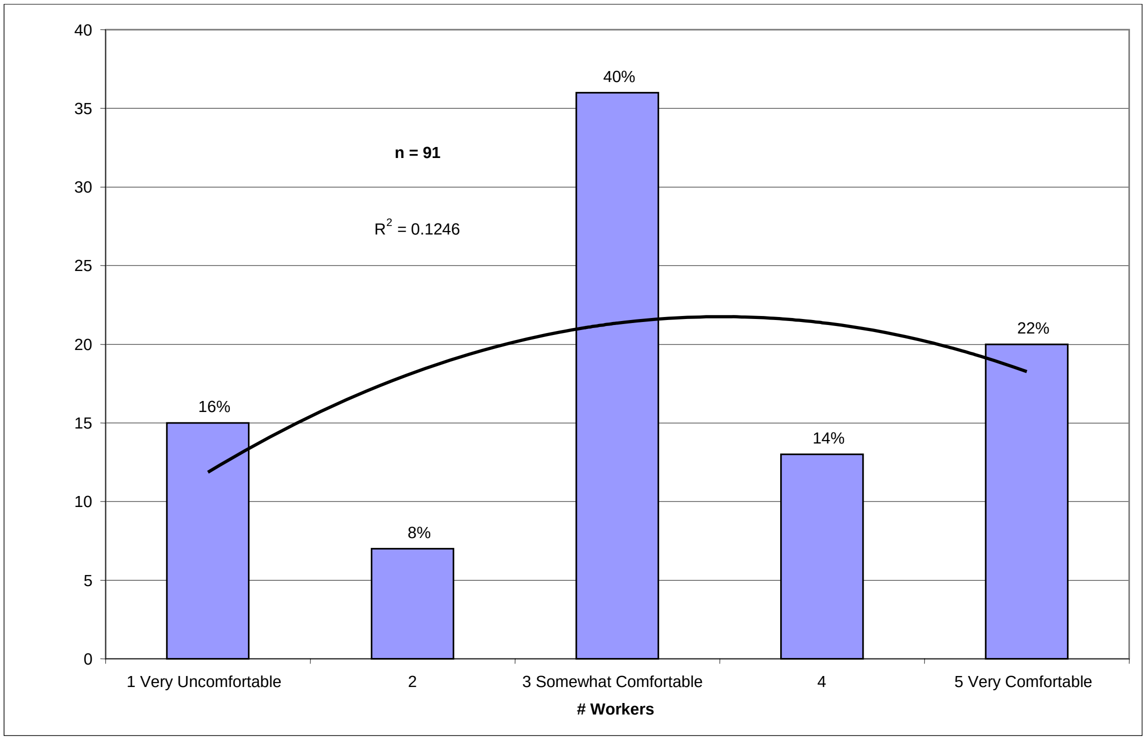


Figure 18: Bottom Crews Comfort with Technology



Figures 17 and 18 show that the majority of crew members in both top- and bottom-performing crews are at least somewhat comfortable with the technology they are being asked to use. For the majority of crew members, their use of computers and more advanced technology at work is likely limited. Foremen, however, tend to use increased levels of technology. It is the foreman who enters data into the HMMS data system on a daily basis for crews. Unfamiliarity or confusion may result in unreliable data entered into the system, which in turn affects the data SCDOT uses when considering budgetary decisions and productivity standards. It is of the utmost importance that crew foremen fully understand how the HMMS system works, the importance of their daily data entry and the implications of not fully understanding their responsibilities.

There is more information in the survey results than is relevant to the scope of this investigation. This survey data could prove to be very useful in the identification of some of the key characteristics of the best-performing crews and individuals in the SCDOT maintenance workforce.

CHAPTER VI

CONCLUSIONS

In order to maximize the efficiency and productivity of the highway maintenance workforce, the SCDOT has attempted to identify optimal crew compositions. It was anticipated that for various activities within the State's maintenance responsibilities, an optimal crew size could be determined. Various performance factors and measurements were delineated for comparison to crew size. Due to limitations in data sample sizes, and the complexities of the interactions between individual crew components, a statistically valid relationship between crew composition and performance could not be determined.

The rankings of crews based on activity type, location and performance factor, although not statistically relevant, will provide the SCDOT with important information with respect to the top-performing crews in each area. These rankings and the crew size scatter plots did, however, begin to indicate that there may be some characteristics of the top-performing crews that are common throughout the State. However, there are simply too many variables and not enough data within the HMMS to produce specific crew configurations. The Daily Work Reports (DWRs) are the primary entry point for data in HMMS, but these reports do not include all of the information that may impact a crew's performance more profoundly than its crew size. For instance, traffic control problems are not recorded (although notes may be made by a foreman as deemed necessary) and may have a dramatic impact on work productivity and efficiency.

The cost-per-unit accomplished performance criteria became the primary criteria by which the crews were compared to determine optimal configurations. Wide ranges of efficiency with regard to this criterion were observed. When the Activity Composite Score (ACS) was developed using the cost-per-unit accomplished and ranked based on county type, activity type and work description, a more comprehensive performance comparison could be made. Several crews from each county for the shoulders and ditches, surface repairs, and driveways activities were identified as the top performing crews within the state. A scatter plot was also developed comparing crew size and the ACS for each activity and county type. No statistically significant regressions were apparent and the scatter in the diagrams indicated that there is not a strong relationship between a crew's size and performance. There is, however, a strong indication that the characteristics and makeup of the top-performing crews may contribute to their performance and should be investigated.

The equipment optimization analysis determined that, in many situations, crews have pieces of equipment assigned for a particular work description that are unnecessary. As demonstrated by interviews with each county's resident maintenance engineer, it can be surmised that under-utilized equipment is often used only to obtain desired levels of equipment utilization and may not be the equipment preferred by the crew for the activity. On one particular occasion, the researcher witnessed a crew paving roads with an undersized machine. While a proper grade and surface could be achieved with this equipment, it would take several extra hours of time. The reason this piece was being utilized in this particular occasion was the desire to obtain a certain utilization rate in order to replace equipment. The optimized equipment usage tables should allow the SCDOT engineers to reorganize equipment suggestions for different types of work and better utilize resources while keeping equipment utilization rates at the required levels.

Crew foremen are of the utmost importance to the SCDOT's maintenance crews. They are primarily responsible for the work and performance in the field and they are critical to the SCDOT's analysis of the crew's performance. The foremen are responsible for filling out the DWRs that are the basis for much of the HMMS system. A total of 56 foreman completed surveys for this research. The vast majority of the foreman, over 95%, reported knowledge of performance targets set for their crews. However, the statistic that should be of greatest concern to the SCDOT is that of the 56 foremen surveyed, 32% of them are not concerned at all with reaching these performance targets. If the SCDOT is genuinely relying on these targets as a benchmark for their maintenance crews, they need to have incentives for the crew foremen to reach these targets. Incentives that filter down to all levels of a crew would be even more beneficial. There are many different programs in departments of transportation as well as in other construction industry sectors that have proven to provide incentives for the consistent performance of workers. One such program is the North Carolina Department of Transportation's skill based pay program, which has yielded positive results, generated enthusiasm and achieved higher levels of performance within its workforce. Such a program may be worthy of consideration by SCDOT.

Recommendations for the SCDOT

Although the conclusions of this research do not support the original hypothesis that a crew's performance would be dependent on the size of the crew, it found that the performance rankings can be used to identify the top-performing crews for individual activities and county types. It is the identification of these top crews that may, with additional investigation, determine the specific characteristics and components of highly productive crews.

There are several points of action that should be taken, in addition to the study of the top crews, which will enhance productivity. The first would be to make sure that the SCDOT has a firm grip of their definition of productivity (Hanna, Amir; 2001). For this particular study, a desire was expressed to use cost-unit accomplished as the primary metric for productivity measurement. This may or may not be the best approach for it as a government entity, as much of its work is driven by budgetary decisions. However, a formal definition provided from upper management would provide a solid base from which to work in this regard. In his research, Harry Hatry provides several appropriate and proven definitions of productivity that may be easily applied to the construction public sectors. He cites that reasons for lack of productivity improvement and measurement in the public sector is a lack of understanding, thus developing a concrete definition for use by the SCDOT (even if it has several parts) and educating its people would be a good initial starting point.

Secondly, the SCDOT should take a more focused approach to its productivity analysis and study. It has been proven that a narrower approach to productivity analysis will yield greater results and be most effective (Ellis, Ralph D. and Lee, Seung-hyun; 2006). This approach will also help to identify the many factors that will affect labor productivity and account for these factors in analysis. In a more broad approach, it is nearly impossible to identify all factors and incorporate them into an analysis. Taken one step further, an approach that focuses on the individual level will further amplify productivity improvements, given that every construction situation, and every individual worker, is different. Personal factors such as health (both mental and physical), attitude, experience and age may have a great influence on labor productivity (Hanna, Amir; 2001). This also ties into ensuring that all the supervisors at the SCDOT are properly trained, as a lack of management skill will result in decreases in labor productivity (Rojas, Eddy M. and Peerapong, Aramvareekul; 2003). Supervisors interact with workers on an individual level and must understand how to effectively manage their workforce by placing emphasis on each individual employee, as well as by understanding that different responses will come from the same reward. If the SCDOT manages to instill these values in its supervisors, productivity increases should be seen.

The Construction Industry Institute’s research cites that a lack of resources as the biggest factor in decreasing labor productivity on a construction site. Through analysis of observations, survey data and interviews, it is not believed that the SCDOT suffers from a lack of resources being provided to its workers. However, due to the constant pressure of equipment utilization rates driving decisions, a misallocation of resources is most likely affecting productivity levels. Examining these rates in more detail, as well as using the equipment optimization charts to further narrow suggestions and choices of equipment for crews should effect increased productivity.

Finally, the SCDOT should conduct a more in-depth research project designed to further improve their maintenance crews. This study should focus on studying productivity trends for specific crews on a week by week basis and identify reasons for increased or decreased productivity levels during the study time period. This will allow the SCDOT to identify the items that have the most influence on its crew’s productivity levels and address them. While there will be many factors that affect productivity, it will never be feasible to properly address them all. Performing this type of study with a small sample size, and thoroughly covering the chosen crews over a long enough time period, is the best way to identify exactly what has the greatest effect on its labor crews' productivity levels.

It is the desire of the researchers that the SCDOT use the data and the crew rankings in this research to further analyze the components of top-performing workers and create a model for productive and effective maintenance crews that can be replicated throughout the State. This, along with implementation of the several other suggestions cited above, should yield productivity increases across the board in a fiscally-responsible fashion that benefits the citizens of South Carolina through efficient use of their tax revenue.

APPENDICES

APPENDIX A

Maintenance Worker Survey

Crew #__________

SCDOT Maintenance Crew Survey

1. What is your age? _____________

2. What is your gender? ☐ Female ☐ Male

3. What is your highest level of education achieved?

☐ 0-8 years of school
☐ Some high school
☐ High school diploma
☐ GED equivalent
☐ Completed vocational or technical program
☐ Some college (No degree)
☐ Associate degree (2 year program)
☐ Bachelors degree (4 year program)
☐ Some post graduate education (Masters, Ph.D.)
☐ Masters degree
☐ Ph.D.
☐ Other (please specify)_______________

4. What is your current job title? ____________

5. How long have you been at this current job? ____________

6. Have you held any other positions with the DOT? If yes please list.

7. Do you know how to use a computer? ☐ YES ☐ NO

8. How long have you been using a computer? __________ years

9. How comfortable are you with performing the following tasks?

a. Email

1	2	3	4	5
Very Uncomfortable		Somewhat Comfortable		Very Comfortable

b. Word processing

1	2	3	4	5
Very Uncomfortable		Somewhat Comfortable		Very Comfortable

c. Spreadsheet (Excel)

1	2	3	4	5
Very Uncomfortable		Somewhat Comfortable		Very Comfortable

d. Scheduling

1	2	3	4	5
Very Uncomfortable		Somewhat Comfortable		Very Comfortable

e. Other software ______________

1	2	3	4	5
Very Uncomfortable		Somewhat Comfortable		Very Comfortable

10. In general, how comfortable do you feel with the technology you are asked to use?

1	2	3	4	5
Very Uncomfortable		Somewhat Comfortable		Very Comfortable

11. What type of work does your crew generally perform?

12. How many people are in your crew? ____________

13. Did you have any influence on the makeup of your crew? Are you allowed to make suggestions on who is apart of your crew? Explain

14. Are performance targets set for your crew? ☐ YES ☐ NO

15. Do you know what these targets are? ☐ YES ☐ NO (SKIP TO QUESTION 18)

16. If so, do you believe these targets to be realistic? ☐ YES ☐ NO

17. Please give an example of a performance target and its corresponding activity?

18. Are you concerned with reaching performance targets? Why or why not? Explain? ☐ YES ☐ NO

19. Do you think that there are too many people in your crew? ☐ YES ☐ NO

20. Do you think that you need more people in your crew? ☐ YES ☐ NO

21. Does your crew take shortcuts in some areas because you do not have enough people to properly perform the work? ☐ YES ☐ NO

22. Is it common for your flagman to have other tasks because you are shorthanded? ☐ YES ☐ NO

23. Is the workload correctly distributed among the members of your crew? ☐ YES ☐ NO

24. On average, how many members from your crew are missing on any given day because:

a) They are absent or on leave?

b) They are working with another crew?

25. Have you ever been asked to perform work with another crew other than your own? ☐ YES ☐ NO
If yes what type of crew? Approximately how many times a month does this occur?

For the following questions please rank answers on a scale of 1-10, with 1 being poor and 10 being excellent:

26. Your personal performance over the past year __________

27. Your crew's performance over the past year __________

28. How well does your crew get along as a team _________

29. Your crew's performance relative to other crews in the DOT _________

30. Are you a foreman? _________ (If yes please skip the next question #31)

31. The performance of your crew's foreman over the past year _________

32. The overall work culture within the DOT _________

33. Your satisfaction with the DOT's pay, benefits and hours _________

34. How well the DOT communicates with its employees _________

35. Equipment:

    a. Quality _________

    b. Availability (having the proper equipment) _________

    c. Maintenance _________

36. Please list any other suggestions or comments

For the following questions please circle the answer that best describes your feelings with regards to the statement above:

37. I am satisfied with my current position at the DOT

1 Strongly Disagree	2 Somewhat Disagree	3 Neither Agree or Disagree	4 Somewhat Agree	5 Strongly Agree

38. I have a strong working relationship with the other members of my crew

1 Strongly Disagree	2 Somewhat Disagree	3 Neither Agree or Disagree	4 Somewhat Agree	5 Strongly Agree

39. I am provided with the proper equipment I need to best complete my job

1 Strongly Disagree	2 Somewhat Disagree	3 Neither Agree or Disagree	4 Somewhat Agree	5 Strongly Agree

40. My suggestions are heard and taken into account by my superiors

1 Strongly Disagree	2 Somewhat Disagree	3 Neither Agree or Disagree	4 Somewhat Agree	5 Strongly Agree

41. My crew the has the correct number of people to perform the work being asked of us

1 Strongly Disagree	2 Somewhat Disagree	3 Neither Agree or Disagree	4 Somewhat Agree	5 Strongly Agree

42. I have been properly trained by the DOT in the skillset needed to perform my job

1 Strongly Disagree	2 Somewhat Disagree	3 Neither Agree or Disagree	4 Somewhat Agree	5 Strongly Agree

THANK YOU!

APPENDIX B

Crew Information Tables

Table B1: Maintenance Crew Totals by County

County	Total Workers
Bamberg	39
McCormick	26
York	81
Richland	121
Greenville	73
Lexington	110

Table B2: Crew Data for Bamberg County

Crew #	Organization Description	Class Code	Class Description	Band/ Level	#	Workers/ Crew
70503	BAMBERG - COMPLAINTS/ DRIVEWAYS	KC20	TRADE SPECIALIST II	2A	1	9
		KC20	TRADE SPECIALIST II	2B	4	
		KC20	TRADE SPECIALIST II	2D	2	
		KC30	TRADE SPECIALIST III	3B	2	
70505	BAMBERG - EQUIPMENT SHOP	AC05	SUPPLY SPECIALIST III	3C	1	5
		KC50	TRADE SPECIALIST IV	5B	1	
		KD05	MECHANIC I	2D	1	
		KD15	MECHANIC III	4A	2	
70512	BAMBERG - COMPLAI/ DRIVEWAY/ PATCH	KC20	TRADE SPECIALIST II	2B	4	9
		KC20	TRADE SPECIALIST II	2D	3	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4B	1	
70513	BAMBERG - DITCHES/ DRIVEWAYS	KC20	TRADE SPECIALIST II	2B	3	9
		KC20	TRADE SPECIALIST II	2D	5	
		KC40	TRADE SPECIALIST IV	4C	1	
70515	BAMBERG - MOWING/ COMPLAINTS	KC20	TRADE SPECIALIST II	2A	1	7
		KC20	TRADE SPECIALIST II	2B	4	
		KC20	TRADE SPECIALIST II	2D	1	
		KC40	TRADE SPECIALIST IV	4B	1	

Table B3: Crew Data for McCormick County

Crew #	Organization Description	Class Code	Class Description	Band/ Level	#	Workers/ Crew
23305	MCCORMICK - EQUIPMENT SHOP	AC05	SUPPLY SPECIALIST III	3A	1	4
		KC50	TRADE SPECIALIST IV	5A	1	
		KD15	MECHANIC III	4A	2	
23311	MT CARMEL - DRAIN/ DRIVE/ PATCH	KC20	TRADE SPECIALIST II	2B	2	4
		KC20	TRADE SPECIALIST II	2D	1	
		KC40	TRADE SPECIALIST IV	4A	1	
23312	MCCORMICK - DRAIN/ DRIVE/ PATCH	KC20	TRADE SPECIALIST II	2B	2	6
		KC20	TRADE SPECIALIST II	2C	1	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4A	1	
23313	MCCORMICK - MOWING/ ROW	KC20	TRADE SPECIALIST II	2B	3	6
		KC20	TRADE SPECIALIST II	2C	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4A	1	
23314	MCCORMICK -SIGN	KC30	TRADE SPECIALIST III	3B	1	1
23315	MCCORMICK-AMZ LIMB TRIMMING	KC20	TRADE SPECIALIST II	2B	1	5
		KC20	TRADE SPECIALIST II	2C	2	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4A	1	

Table B4: Crew Data for York County

Crew #	Organization Description	Class Code	Class Description	Band/ Level	#	Workers/ Crew
44605	YORK -EQUIPMENT SHOP	AC05	SUPPLY SPECIALIST III	3A	1	8
		KC50	TRADE SPECIALIST IV	5A	1	
		KD15	MECHANIC III	4A	3	
		KD15	MECHANIC III	4B	3	
44611	YORK - PATCHING LITTER REMOVAL	KC20	TRADE SPECIALIST II	2C	2	7
		KC20	TRADE SPECIALIST II	2D	3	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4C	1	
44612	YORK -EAST ROCK HILL SECTION	KC20	TRADE SPECIALIST II	2B	1	6
		KC20	TRADE SPECIALIST II	2C	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC30	TRADE SPECIALIST III	3C	1	
		KC40	TRADE SPECIALIST IV	4A	1	
44613	FORT MILL/ TEGA CAY SECTION	KC20	TRADE SPECIALIST II	2C	2	6
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	1	

		KC40	TRADE SPECIALIST IV	4A	1	
44614	YORK -DITCHES & SHOULDERS	KC20	TRADE SPECIALIST II	2B	2	7
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	2	
		KC40	TRADE SPECIALIST IV	4A	1	
44615	YORK -SIGNS & SIGNALS	KC20	TRADE SPECIALIST II	2B	2	8
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4A	1	
44616	YORK -BRIDGE MAINTENANCE	KC20	TRADE SPECIALIST II	2B	1	5
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4C	1	
44617	YORK - DRIVEWAYS/ REQUESTS	KC20	TRADE SPECIALIST II	2A	1	7
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4C	1	
44618	YORK-ROCKHILL-DRIVEWAYS	KC20	TRADE SPECIALIST II	2C	1	7
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC30	TRADE SPECIALIST III	3B	2	
		KC40	TRADE SPECIALIST IV	4C	1	
44619	YORK-WEST ROCK HILL SECTION	KC20	TRADE SPECIALIST II	2B	2	4
		KC20	TRADE SPECIALIST II	2C	1	
		KC40	TRADE SPECIALIST IV	4A	1	
44620	YORK -I-77 SPECIAL PROJECTS	KC20	TRADE SPECIALIST II	2A	1	7
		KC20	TRADE SPECIALIST II	2B	1	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC40	TRADE SPECIALIST IV	4A	1	
44621	YORK - IRVM & LITTER REMOVAL	KC20	TRADE SPECIALIST II	2A	1	9
		KC20	TRADE SPECIALIST II	2B	1	
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC30	TRADE SPECIALIST III	3C	1	
		KC40	TRADE SPECIALIST IV	4C	1	

Table B5: Crew Data for Richland County

Crew #	Organization Description	Class Code	Class Description	Band /Level	#	Workers/ Crew
14005	RICHLAND - EQUIPMENT SHOP	AC03	SUPPLY SPECIALIST II	2A	1	12
		AC03	SUPPLY SPECIALIST II	2B	1	
		AC05	SUPPLY SPECIALIST III	3C	1	
		KC20	TRADE SPECIALIST II	2C	1	
		KC50	TRADE SPECIALIST IV	5C	1	
		KD05	MECHANIC I	2B	1	
		KD05	MECHANIC I	2C	1	
		KD05	MECHANIC I	2D	1	
		KD15	MECHANIC III	4A	2	
		KD15	MECHANIC III	4B	1	
		KD15	MECHANIC III	4C	1	
14015	RICHLAND - SIGN/ PAVEMENT MARK	KC20	TRADE SPECIALIST II	2A	1	11
		KC20	TRADE SPECIALIST II	2B	5	
		KC20	TRADE SPECIALIST II	2C	1	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC40	TRADE SPECIALIST IV	4B	1	
14020	RICHLAND -4020 SECTION	KC20	TRADE SPECIALIST II	2A	2	9
		KC20	TRADE SPECIALIST II	2B	1	
		KC20	TRADE SPECIALIST II	2D	3	
		KC30	TRADE SPECIALIST III	3A	2	
		KC40	TRADE SPECIALIST IV	4C	1	
14025	RICHLAND -4025 SECTION	KC20	TRADE SPECIALIST II	2A	2	7
		KC20	TRADE SPECIALIST II	2B	2	
		KC20	TRADE SPECIALIST II	2C	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4A	1	
14030	RICHLAND -4030 SECTION	KC20	TRADE SPECIALIST II	2A	3	6
		KC20	TRADE SPECIALIST II	2B	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4C	1	
14035	RICHLAND - EASTOVER-SHED	KC20	TRADE SPECIALIST II	2B	1	8
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	3	
		KC40	TRADE SPECIALIST IV	4B	1	
14040	RICHLAND - BALLENTINE-SHED	KC20	TRADE SPECIALIST II	2A	1	7
		KC20	TRADE SPECIALIST II	2B	4	
		KC30	TRADE SPECIALIST III	3A	1	
		KC50	TRADE SPECIALIST IV	5A	1	
14050	RICHLAND -4050	KC20	TRADE SPECIALIST II	2A	2	9

	RICHLAND - 4050 SECTION	KC20	TRADE SPECIALIST II	2B	2	
		KC20	TRADE SPECIALIST II	2C	1	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4B	1	
14055	RICHLAND - LITTER/ DRAINAGE	KC20	TRADE SPECIALIST II	2B	1	6
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4C	1	
14060	RICHLAND - ASPHALT	KC20	TRADE SPECIALIST II	2D	1	5
		KC30	TRADE SPECIALIST III	3A	3	
		KC40	TRADE SPECIALIST IV	4B	1	
14065	RICHLAND - NORTH AREA-DITCH	KC20	TRADE SPECIALIST II	2A	1	8
		KC20	TRADE SPECIALIST II	2B	2	
		KC20	TRADE SPECIALIST II	2D	2	
		KC30	TRADE SPECIALIST III	3A	2	
		KC40	TRADE SPECIALIST IV	4C	1	
14070	RICHLAND - BRIDGE-CONST/ MAINT	KC20	TRADE SPECIALIST II	2A	1	6
		KC20	TRADE SPECIALIST II	2B	1	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC40	TRADE SPECIALIST IV	4C	1	
14075	RICHLAND-HERBICIDE/ INMATE	KC20	TRADE SPECIALIST II	2A	2	4
		KC30	TRADE SPECIALIST III	3A	1	
		KC30	TRADE SPECIALIST III	3B	1	
14080	RICHLAND - SOUTH AREA-DITCH	KC20	TRADE SPECIALIST II	2A	1	8
		KC20	TRADE SPECIALIST II	2B	3	
		KC20	TRADE SPECIALIST II	2C	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC40	TRADE SPECIALIST IV	4B	1	
14085	RICHLAND - INTERSTATE-TC/GRAIL	KC20	TRADE SPECIALIST II	2A	1	4
		KC20	TRADE SPECIALIST II	2B	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4C	1	
14090	RICHLAND - MOWING/ IRVM	KC20	TRADE SPECIALIST II	2A	4	11
		KC20	TRADE SPECIALIST II	2B	1	
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	2	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4A	1	

Table B6: Crew Data for Greenville County

Crew #	Organization Description	Class Code	Class Description	Band/ Level	#	Workers/ Crew
32305	GREENVILLE - EQUIPMENT SHOP	AC03	SUPPLY SPECIALIST II	2C	1	12
		AC05	SUPPLY SPECIALIST III	3B	1	
		KC20	TRADE SPECIALIST II	2D	1	
		KC50	TRADE SPECIALIST IV	5A	1	
		KD05	MECHANIC I	2B	1	
		KD05	MECHANIC I	2D	1	
		KD15	MECHANIC III	4A	4	
		KD15	MECHANIC III	4C	2	
32311	GREENVILLE	KC20	TRADE SPECIALIST II	2B	2	6
		KC20	TRADE SPECIALIST II	2C	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4A	1	
32312	GREENVILLE -N GREEN SHED 1	KC20	TRADE SPECIALIST II	2A	1	6
		KC20	TRADE SPECIALIST II	2B	2	
		KC30	TRADE SPECIALIST III	3A	2	
		KC40	TRADE SPECIALIST IV	4B	1	
32313	GREENVILLE -N GREEN SHED 2	KC20	TRADE SPECIALIST II	2A	1	6
		KC20	TRADE SPECIALIST II	2B	3	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4A	1	
32314	GREENVILLE - PLEASANT HILL SHED	KC20	TRADE SPECIALIST II	2A	1	6
		KC20	TRADE SPECIALIST II	2B	3	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4A	1	
32315	GREENVILLE - FORK SHOALS SHED	KC20	TRADE SPECIALIST II	2A	2	5
		KC20	TRADE SPECIALIST II	2B	1	
		KC20	TRADE SPECIALIST II	2D	1	
		KC40	TRADE SPECIALIST IV	4A	1	
32316	GREENVILLE - DRAINAGE	KC20	TRADE SPECIALIST II	2A	1	6
		KC20	TRADE SPECIALIST II	2B	1	
		KC20	TRADE SPECIALIST II	2C	1	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4A	1	
32319	GREENVILLE - BRIDGE	KC20	TRADE SPECIALIST II	2B	1	3
		KC20	TRADE SPECIALIST II	2D	1	
		KC50	TRADE SPECIALIST IV	5A	1	
32320	GREENVILLE - RETREATMENT	KC20	TRADE SPECIALIST II	2B	2	7
		KC20	TRADE SPECIALIST II	2C	1	
		KC20	TRADE SPECIALIST II	2D	1	

		KC30	TRADE SPECIALIST III	3A	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4A	1	
32330	GREENVILLE - SIGN	HD40	ENG GEOD TECH II	3A	1	7
		KC20	TRADE SPECIALIST II	2A	3	
		KC20	TRADE SPECIALIST II	2B	2	
		KC40	TRADE SPECIALIST IV	4A	1	
32331	GREENVILLE - SIMPSONVILLE SHED	KC20	TRADE SPECIALIST II	2A	3	9
		KC20	TRADE SPECIALIST II	2B	1	
		KC20	TRADE SPECIALIST II	2C	1	
		KC20	TRADE SPECIALIST II	2D	2	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4A	1	

Table B7: Crew Data for Lexington County

Crew #	Organization Description	Class Code	Class Description	Band/ Level	#	Workers/ Crew
13205	LEXINGTON - EQUIPMENT SHOP	AC03	SUPPLY SPECIALIST II	2B	2	9
		AC05	SUPPLY SPECIALIST III	3A	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC50	TRADE SPECIALIST IV	5A	1	
		KD05	MECHANIC I	2B	1	
		KD10	MECHANIC II	3A	1	
		KD15	MECHANIC III	4A	2	
13206	LEXINGTON -W COLA-EQUIPME SHOP	AC05	SUPPLY SPECIALIST III	3B	1	4
		KD05	MECHANIC I	2B	1	
		KD10	MECHANIC II	3B	1	
		KD15	MECHANIC III	4B	1	
13215	LEXINGTON - SIGNS/ PAINT	KC20	TRADE SPECIALIST II	2B	2	7
		KC20	TRADE SPECIALIST II	2C	1	
		KC20	TRADE SPECIALIST II	2D	2	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4C	1	
13220	LEXINGTON – MOWING & PATCHING	KC20	TRADE SPECIALIST II	2B	4	10
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	2	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4C	1	
13225	LEXINGTON - DRAINAGE	KC20	TRADE SPECIALIST II	2B	2	7
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4C	1	
13230	LEXINGTON - IRVM/ HERBICIDE	KC20	TRADE SPECIALIST II	2D	1	2
		KC40	TRADE SPECIALIST IV	4C	1	
13240	LEXINGTON -FULL DEPTH PATCHING	KC20	TRADE SPECIALIST II	2B	3	7
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC40	TRADE SPECIALIST IV	4B	1	
13242	LEXINGTON - CONCRETE	KC20	TRADE SPECIALIST II	2B	3	5
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4A	1	
13245	LEXINGTON -D1- BRIDGE	KC20	TRADE SPECIALIST II	2C	1	4
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC50	TRADE SPECIALIST IV	5A	1	
13250	LEXINGTON - INTERSTATE	KC20	TRADE SPECIALIST II	2A	1	6
		KC20	TRADE SPECIALIST II	2B	1	

		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3B	2	
		KC40	TRADE SPECIALIST IV	4B	1	
13260	LEXINGTON -W COLA-MOW/ PATCH	KC20	TRADE SPECIALIST II	2B	1	5
		KC20	TRADE SPECIALIST II	2C	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4A	1	
13265	LEXINGTON -W COLA-DRAINAGE	KC20	TRADE SPECIALIST II	2A	1	7
		KC20	TRADE SPECIALIST II	2B	1	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC30	TRADE SPECIALIST III	3C	1	
		KC40	TRADE SPECIALIST IV	4C	1	
13270	LEXINGTON - PELION-MOW/ PATCH	KC20	TRADE SPECIALIST II	2A	3	6
		KC20	TRADE SPECIALIST II	2B	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC40	TRADE SPECIALIST IV	4A	1	
13275	LEXINGTON - PELION- DRAINAGE	KC20	TRADE SPECIALIST II	2A	1	8
		KC20	TRADE SPECIALIST II	2B	2	
		KC30	TRADE SPECIALIST III	3A	2	
		KC30	TRADE SPECIALIST III	3B	2	
		KC40	TRADE SPECIALIST IV	4C	1	
13280	LEXINGTON - PELION-DITCHING	KC20	TRADE SPECIALIST II	2B	2	6
		KC20	TRADE SPECIALIST II	2C	1	
		KC30	TRADE SPECIALIST III	3B	2	
		KC40	TRADE SPECIALIST IV	4A	1	
13285	LEXINGTON - DITCHING	KC20	TRADE SPECIALIST II	2B	2	8
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	1	
		KC30	TRADE SPECIALIST III	3B	1	
		KC40	TRADE SPECIALIST IV	4C	1	
13290	LEXINGTON - BATESBURG- LEESVILLE	KC20	TRADE SPECIALIST II	2B	3	9
		KC20	TRADE SPECIALIST II	2C	2	
		KC20	TRADE SPECIALIST II	2D	1	
		KC30	TRADE SPECIALIST III	3A	2	
		KC40	TRADE SPECIALIST IV	4C	1	

APPENDIX C

Activity Composite Scores for Shoulder and Ditch Activities

Table C1: Top Performing Shoulder and Ditch Crews

	Crew #	# Workers	Activity Composite Score (ACS)	Rank
URBAN	14080	8	3.2	1
	32313	6	3.4	2
	32316	6	5	3
	14065	8	5	4
	14035	8	5.5	5
MIXED	13250	6	2	1
	13250	6	3	2
	13270	6	4.7	3
	44614	7	5.6	4
	13285	8	5.75	5
RURAL	23312	6	2	1
	23315	5	3	2
	70515	7	3.2	3
	70503	9	3.3	4
	23311	4	3.7	5

Table C2: Shoulder and Ditch Crew Rankings for Urban Counties

Crew #	Description	# Workers	Work Desc. Ranks	ACS	Rank
14080	SOUTH AREA DITCH	8	11,2,1,1,3,1	3.2	1
32313	N GREEN SHED 2	6	3,2,1,5,6	3.4	2
32316	DRAINAGE	6	4,3,13,1,4	5	3
14065	NORTH AREA DITCH	8	12,8,3,3,2,2,	5	4
14035	EASTOVER SHED	8	9,5,2,7,5,5	5.5	5
32314	PLEASANT HILL SHED	6	1,6,15,4	6.5	6
32311	GREENVILLE	6	13,1,7,3,14,7	7.5	7
32331	SIMPSONVILLE SHED	9	10,5,5,8,11,7	7.7	8
14025	4025 SECTION	7	5,10,9,8	8	9
14050	4050 SHED	9	6,11,8	8.3	10
14020	4020 SECTION	9	14,6,1,9,13	8.6	11
14030	4030 SECTION	6	18,7,6,12,10,3	9.3	12
14085	INTERSTATE/TC/GRAIL	4	7,4,17	9.3	13
32312	N GREEN SHED 1	6	17,8,4,6,12	9.4	14
32315	FORK SHOALS SHED	5	20,2,15,4	10.3	15
14040	BALLENTINE SHED	7	15,17,14	15.3	16
32319	BRIDGE	3	21,16,19	18.7	17

Table C3: Shoulder and Ditch Crew Rankings for Mixed Counties

Crew #	Description	# Workers	Work Desc. Ranks	ACS	Rank
13250	INTERSTATE	6	2,2,2,3,1	2	1
13250	PELION DITCHING	6	3,7,1,1	3	2
13270	PELION MOW/PATCH	6	4,8,2	4.7	3
44614	DITCHES & SHOULDERS	7	13,5,3,3,4	5.6	4
13285	DITCHING	8	16,2,2,3	5.75	5
13275	PELION DRAINAGE	8	11,1,5,4,8,6,7	6	6
44612	EAST ROCK HILL	6	8,7,4,9,5	6.6	7
13290	BATESBURG/LEESVILLE	9	3,3,6,6,11,12	6.8	8
44620	I77 SPECIAL PROJS	7	9,10,5,5,6	7	9
13242	CONCRETE	5	6,3,4,12,10,13	8	10
13225	DRAINAGE	7	10,5,9,9,13	9.2	11
44613	FORT MILL/TEGA CAY	6	1,14,15,7,10	9.4	12
13265	W/COLA DRAINAGE	7	7,4,15,11,15	10.4	13
13220	MOW/PATCH	10	15,2,17	11.3	14
44617	DRIVEWAYS/REQUESTS	7	17,13,13,8,9	12	15
13260	W/COLA MOW/PATCH	5	16,12,8	12	16
44618	WEST ROCK HILL	4	18,11,12,10,14	13	17
44618	ROCKHILL-DRIVEWAYS	7	12,16,14,14,16	14.4	18
13240	FULL DEPTH PATCHING	7	14,18,17,11	15	19

Table C4: Shoulder and Ditch Crew Rankings for Rural Counties

Crew #	Description	# Workers	Work Desc. Ranks	ACS	Rank
23312	MCCORMICK DRAIN DRIVE PATCH	6	1,1,2,2,5,3,1,1	2	1
23315	AMZ/LIMB/TRIM	5	2,2,5	3	2
70515	MOW/COMPLAINTS	7	3,1,1,3,8	3.2	3
70503	COMPLAINTS/DRIVEWAYS	9	5,4,1,3,4,3	3.3	4
23311	MT CARMEL	4	3,6,1,4,6,2	3.7	5
70512	COMPLAINT/DRIVE/PATCH	9	6,2,3,6,2,6	4.2	6
70513	DITCHES/DRIVEWAYS	9	4,5,4,7,2,5,4	4.4	7

APPENDIX D

Activity Composite Scores for Surface Repair Activities

Table D1: Top Performing Surface Repair Crews

	Crew #	# Workers	ACS	Rank
URBAN	14060	5	4.4	1
	32331	9	6.2	2
	32312	6	6.3	3
	32313	6	6.3	4
	32314	6	6.3	5
MIXED	13220	10	5.1	1
	44612	6	5.4	2
	13285	8	5.4	3
	13290	9	6.6	4
	44613	6	7	5
RURAL	23311	4	2.5	1
	70512	9	3	2
	23315	5	3.2	3
	23312	6	3.25	4
	70513	9	4.4	5

Table D2: Surface Repair Crew Rankings for Urban Counties

Crew #	Description	# Workers	Work Desc. Ranks	ACS	Rank
14060	ASPHALT	5	2,13,2,2,3	4.4	1
32331	SIMPSONVILLE SHED	9	3,2,1,14,8,6,5,4,3,14,8	6.2	2
32312	N GREEN SHED 1	6	1,9,4,11,9,9,1,3,10	6.3	3
32313	N GREEN SHED 2	6	5,5,5,5,7,12,5	6.3	4
32314	PLEASANT HILL SHED	6	9,6,10,6,7,3,6,3	6.3	5
14025	4025 SECTION	7	6,8,17,1,7,7,10,7,4,5	7.2	6
14050	4050 SHED	9	8,9,13,14,5,1,6,5,6	7.6	7
32315	FORK SHOALS SHED	5	17,12,3,3,3,8,11	8.1	8
14065	NORTH AREA DITCH	8	19,4,18,2,2,10,2	8.1	9
32320	RETREATMENT	7	14,1,8,4,11,12,11	8.7	10
32311	GREENVILLE	6	11,7,6,7,18,14	10.5	11
14035	EASTOVER SHED	8	13,9,10,8,12,12,12,8	10.5	12
14085	INTERSTATE/TC/GRAIL	4	2,18,16,15,2	10.6	13
14070	BRIDGE CONST/MAINT	6	4,15,13	10.7	14
14030	4030 SECTION	6	12,14,13,9,7,11,10,13,10	11	15
14080	SOUTH AREA DITCH	8	16,20,1,1,17	11	16
32316	DRAINAGE	6	18,12,3,17,4,16,11,13	11.4	17
14040	BALLENTINE SHED	7	7,4,22,9,16,4,10,13,19	11.6	18
14020	4020 SECTION	9	10,16,15,9,15,11,14,8	12.3	19
14015	SIGN/ PAVEMENT MARK	11	15,21,20,6	15.5	20
32319	BRIDGE	3	23,8,17,17	16.3	21

Table D3: Surface Repair Crew Rankings for Mixed Counties

Crew #	Description	# Workers	Work Desc. Ranks	ACS	Rank
13220	MOW/PATCH	10	3,3,5,8,3,2,12	5.1	1
44612	EAST ROCK HILL	6	4,4,8,9,5,7,1	5.4	2
13285	DITCHING	8	7,2,3,7,8	5.4	3
13290	BATESBURG/LEESVILLE	9	2,6,4,12,4,4,14	6.6	4
44613	FORT MILL/TEGA CAY	6	13,3,10,5,9,2	7	5
13240	FULL DEPTH PATCHING	7	8,5,9,1,16,5,11	7.9	6
44618	WEST ROCK HILL	4	12,12,14,6,3,3	8.3	7
13260	W/COLA MOW/PATCH	5	11,8,6,10,11,8	9	8
44620	I77 SPECIAL PROJS	7	18,16,2,12,1,6	9.2	9
13250	INTERSTATE	6	14,1,6,14,13	9.6	10
13275	PELION DRAINAGE	8	9,11,10	10	11
13270	PELION MOW/PATCH	6	15,7,3,15,18,6	10.7	12
44617	DRIVEWAYS/REQUESTS	7	20,1,7,7,24,7	11	13
44611	PATCHING LITTER REMOVAL	7	12,10,15,16,13,10,5	11.6	14
13250	PELION DITCHING	6	19,13,4,17,10	12.6	15
13242	CONCRETE	5	17,9,14,13,15,9	12.8	16
44618	ROCKHILL-DRIVEWAYS	7	18,11,20,4	13.3	17
44614	DITCHES & SHOULDERS	7	26,21,9	18.7	18

Table D4: Surface Repair Crew Rankings for Rural Crews

Crew #	Description	# Workers	Work Desc. Ranks	ACS	Rank
23311	MT CARMEL	4	1,1,3,5	2.5	1
70512	COMPLAINT/DRIVE/PATCH	9	5,4,2,1	3	2
23315	AMZ/LIMB/TRIM	5	3,6,5,1,1	3.2	3
23312	MCCORMICK DRAIN DRIVE PATCH	6	2,2,6,3	3.25	4
70513	DITCHES/DRIVEWAYS	9	4,7,6,2,3	4.4	5

APPENDIX E

Activity Composite Scores for Driveway Activities

Table E1: Top Performing Driveway Crews

	Crew #	# Workers	ACS	Rank
URBAN	32312	6	4.7	1
	32311	6	4.8	2
	32316	6	5.25	3
	32314	6	5.3	4
	14025	7	5.3	5
MIXED	13265	7	3	1
	13260	5	4	2
	13270	6	4.3	3
	13290	9	5.5	4
	13285	8	7	5
RURAL	23311	4	1.5	1
	23312	6	3.2	2
	70512	9	4.3	3
	70513	9	4.7	4
	70503	9	5.3	5

Table E2: Driveway Crew Rankings for Urban Counties

Crew #	Description	# Workers	Work Desc. Ranks	ACS	Rank
32312	N GREEN SHED 1	6	4,7,3,5	4.7	1
32311	GREENVILLE	6	8,3,6,2	4.8	2
32316	DRAINAGE	6	13,1,1,6	5.25	3
32314	PLEASANT HILL SHED	6	9,2,5	5.3	4
14025	4025 SECTION	7	2,8,9,2	5.3	5
32315	FORK SHOALS SHED	5	11,6,4,1	5.5	6
14030	4030 SECTION	6	5,5,7	5.7	7
32313	N GREEN SHED 2	6	6,10,2	6	8
14020	4020 SECTION	9	7,4,13,4	7	9
14040	BALLENTINE SHED	7	10,9,10,3,3	7	10
32331	SIMPSONVILLE SHED	9	3,14,8	8.3	11
14035	EASTOVER SHED	8	12,12,12,6,1	8.6	12
14050	4050 SHED	9	15,13,10,11,7,4	10	13
14065	NORTH AREA DITCH	8	14,11,14,5	11	14

Table E3: Driveway Crew Rankings for Mixed Counties

Crew #	Description	# Workers	Work Desc. Ranks	ACS	Rank
13265	W/COLA DRAINAGE	7	3,5,1	3	1
13260	W/COLA MOW/PATCH	5	1,2,9,4	4	2
13270	PELION MOW/PATCH	6	8,4,1	4.3	3
13290	BATESBURG/LEESVILLE	9	4,8,8,2	5.5	4
13285	DITCHING	8	15,3,3	7	5
44614	DITCHES & SHOULDERS	7	13,12,2,7	8.5	6
44618	ROCKHILL-DRIVEWAYS	7	13,12,2,7	8.5	7
44618	WEST ROCK HILL	4	6,10,11	9	8
13225	DRAINAGE	7	7,17,5,8	9.3	9
44617	DRIVEWAYS/REQUESTS	7	10,7,12	9.7	10
13242	CONCRETE	5	12,11,13,3	9.8	11
44613	FORT MILL/TEGA CAY	6	17,14,7,6	11	12
44620	I77 SPECIAL PROJS	7	11,9,14	11.3	13

Table E4: Driveway Crew Rankings for Rural Counties

Crew #	Description	# Workers	Work Desc. Ranks	ACS	Rank
23311	MT CARMEL	4	2,2,1,1	1.5	1
23312	MCCORMICK DRAIN DRIVE PATCH	6	4,5,3,3,1	3.2	2
70512	COMPLAINT/DRIVE/PATCH	9	5,4,4	4.3	3
70513	DITCHES/DRIVEWAYS	9	3,6,5	4.7	4
70503	COMPLAINTS/DRIVEWAYS	9	6,7,2,6	5.3	5

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