OPTIMAL MAINTENANCE CREW COMPOSITION AND ENHANCEMENT OF CREW PRODUCTIVITY

FINAL REPORT

SCDOT Research Project 668

Robert W. Schober,
Stefanie G. Brandenburg,
And
Lansford C. Bell

Department of Civil Engineering
Clemson University
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ABSTRACT

The South Carolina Department of Transportation dedicates a large portion of both 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 the research is to begin to identify optimal crew compositions, if possible, and to enhance crew productivity.

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 description and county type. Once crew rankings were identified, the top crews were analyzed to determine the crew configurations for each activity that produced the optimum results. Optimal equipment utilization was also analyzed and improved equipment allocation specifications were developed. 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 for this survey were chosen to be representative of the different areas throughout the state of South Carolina- primarily urban counties, mixed urban and rural counties, and primarily rural counties. Both maintenance workers and maintenance engineers participated in the survey with a total of 382 surveys collected. The data collected from these surveys included demographic information on each worker, information about crews, and opinion data relating to maintenance performance standards and the worker's understanding of those standards.

The data analysis 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 of these things 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 that allowed crews to be compared on a consistent basis. What was determined from this analysis was 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 Activity Composite Score the top five 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 increasing productivity and performance in maintenance crews throughout the State.

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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 its 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 widely in characteristics, but crew performance standards are often estimated at the state level and all counties are expected to meet those same standards. The South Carolina Department of Transportation (SCDOT) partnered with Clemson University to further analyze the performance of their 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 autonomous freedom to use available budget and resources in order to organize and manage their crews. These crew structures vary by county, but most often a county will have one or more crews that perform a specific set of activities. These crews vary in size but each will have a crew foreman and crew members of varying experience and positions. It is the objective of this research that optimum crew compositions and associated equipment resources can be developed to maximize maintenance crew productivity.

There is a vast body of work in the research community addressing labor productivity. This work confirms that the main problem in achieving high levels of labor productivity is the motivation of workers. Generally laborers arrive to work motivated, however, there are factors present in most workplaces that demotivate workers and have a

negative impact on labor productivity. Several research projects designed to implement programs planned to further motivate workers have been met with varying levels of success. There is no one program or set of guidelines that achieves a 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. 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.

The Highway Maintenance Management System (HMMS) was purchased by the SCDOT in order to keep track of all aspects of the maintenance work performed across the state. The system is designed to keep track of the labor, equipment and resources used by each crew across the state for all of the work performed. At the end of a workday, the crew foreman will fill out a Daily Work Report (DWR) that contains all of the information regarding the crews' 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 make comparisons of crews on an even scale. The engineers at the DOT use this data to budget for the following fiscal year as well as track crew performance. One of the advantages of this system is that the data may be organized and sorted in a vast number of ways so that the users may view data as needed. The data is often used to compare a crew's performance to a set of standards developed by the State's engineers. Despite such

quantities of data, it is difficult for the DOT to determine whether or not their allocation of resources and crew members are being used in an optimal way. The development of optimal crew compositions and other factors to improve crew productivity is the goal of this research endeavor. Being able to effectively utilize the maintenance workforce and maintenance equipment, the 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 optimal crew composition for a specific 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 present that impact labor crew productivity, and whether or not revised policies and procedures would improve maintenance crew productivity

- Determine if productivity standards are clearly understood by crew leaders such that the work performed is recorded correctly by activity or work description and 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 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 those standards.

CHAPTER II

LITERATURE REVIEW

Introduction

A thorough literature review has been conducted for this project. Two major areas were researched; the measurement of labor productivity and the motivation of craft workers. This should give the most information on the determination of optimal maintenance crew composition, 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 the use of online databases. The Transportation Research Information Services (TRIS) database provided a bulk of the information. The TRIS database is the world's largest and most comprehensive bibliographic resource on transportation information. Once appropriate keywords were determined, hundreds of resources needed to be 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. Several human resource publications were cited in the literature review as well.

Labor Productivity: Measurement

The literature review had to be divided into two separate parts because there is very little data that addresses the exact problem posed by the research at hand. No research could be found that specifically addresses the types of crew compositions typical of highway maintenance work crews. Thus one of the problems with the search was trying to find data that is relative to the research at hand and that can be used to help determine a better initial 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 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 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

All of this data will have a significant impact on highway maintenance crews and their ability to work effectively.

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 premise of the program is the implementation of systematic maintenance management procedures which are organized by the head engineers of a district in coordination with their maintenance foreman. These procedures are not meant to be inflexible but rather only identified and communicated to all participating members. Desired results should be identified and defined at the onset of the program. These results can 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. Finally, any quality control procedures needed should be addressed as well as making available adequate resources to accomplish the aforementioned goals and results (Smith, K.L., Stivers, M.L., Hoerner, T.E., and Romine, A.R.; 1997). These requirements conform to the issues raised by several of the SCDOT maintenance engineers who were interviewed during the research

process. It is also in line 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 engineer. These productivity standards are initially set by the state and then revised by the engineer (if deemed necessary). The report illustrates examples of how to define the work accomplished and thus theoretically will result in improved, 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 as the data is based on reports from different state departments of transportation that have implemented pieces of the system within their own state 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, while dated, provides good definitions of productivity measurement. Hatry defines the key measurements of productivity as the combination of efficiency and effectiveness. This definition summarized means that being both efficient and effective together means being productive. 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 further goes into detail of how the public sectors vary, rarely using effective productivity measurement. He believes this is due to several reasons. The first is that productivity measurement is not as important to the public sector as a whole 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 on

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 our research because again a good definition of labor productivity is needed in order to be able to recommend an optimized highway maintenance crew.

Assuming that there is a basis for how labor productivity is defined, there is still the question of how the productivity will be measured. The Construction Industry Institute (CII) has done multiple studies on labor productivity measurement using data from many large construction projects across many disciplines. While this may not specifically apply to highway maintenance crews, it still gives 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 is intended to be an introduction to labor productivity. It presents a simple approach to productivity measurement while maintaining several goals. These goals should be simple and inexpensive to implement and maintain, should be timely in providing problem indicators and should be independent of other business systems. The study recognizes the importance of selecting activities, reporting quantities and reporting work hours in order to accurately measure productivity (Construction Industry Institute; 1990). An additional report a decade later was published to illustrate different production planning strategies that can be used to increase labor productivity. One of the major points raised in the report is that a primary reason for decreased productivity across all types of construction was resource availability. Workers don't have the proper resources available to them when needed. Waiting on equipment and/or not having the proper or best equipment for the work at hand is one of the major factors leading to the decrease in labor productivity management (Construction Industry

Institute; 2001). This is exactly one of the issues identified in some of the initial interviews conducted of field workers for this research.

In another study conducted to illustrate other issues that arise when looking at labor productivity in construction projects and giving some additional examples of productivity improvement, 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 was published in the Journal of Management in Engineering. The report results show that management skills and manpower issues were of the highest concern with regards to labor productivity. External factors were considered to have the least impact on productivity. According to the survey responses the five most promising opportunities believed to help increase labor productivity are as follows (Rojas, Eddy M. and Peerapong, Aramvareekul; 2003):

1. Improvement of methods
2. Improvement of training programs
3. Enhancement of worker motivation
4. Improvement of strategic management
5. Improvement of procurement management

This report contrasts the research conducted by CII citing the internal factors of a construction project as most affecting labor productivity instead of the external factor (availability of equipment) cited by CII.

Finally a specific study titled “Measuring Project Level Productivity on Transportation Projects” was conducted and published in the Journal of Construction

Engineering and Management. It applies specifically to our research in that it provides a basis for exactly how one might begin to measure labor productivity at the SCDOT and gives results of several large projects that attempted to implement different labor productivity management techniques. This study initially introduces the development of a method for measuring and analyzing the project level productivity of all project activities over the life of the project. The key aspect of the study is a measurement method and the development of a process to combine multiple simultaneous 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 the validity of the analysis method. Results indicate that productivity can be measured and analyzed at the project level based upon the field data of construction operations and that this is the most effective way of measuring productivity across a large construction project in the transportation industry (Ellis, Ralph D. and Lee, Seung-hyun; 2006). While the SCDOT districts typically will subcontract very large construction projects in their territory, this study shows that measuring productivity at the field level (such as individual maintenance crews) is best, 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 in order to effectively measure the productivity of workers at the field level, the motivation of craft workers needs to be examined. It can be easily deduced that properly motivated workers will be more productive than those who are unmotivated. This has been proven in many

studies across endless types of disciplines. In order to better understand how to motivate highway maintenance crew workers it is important to identify some of the typical demotivators of laborers in the construction industry. One of the best reports found illustrating typical demotivators across different types of construction projects was published in the Business Roundtable. These demotivators:

- 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 can be applied and will affect the SCDOT workers. The report further states that labor workers will motivate themselves given the right conditions and opportunities. Findings of their 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, address workforce management as a general idea across a broad spectrum of construction related projects. The report is derived from the authors combined 25 years experience in observing over 125 different projects. The authors delve into the issues they believe will most greatly affect worker productivity. These are scheduling, crew structure, tool selection, resource allocation, the responsibility given to the craft workers by the foreman/supervisors, and the necessary drive to strive for symbiotic work relationships between craft workers and their foreman/supervisors. The overall thrust of the report is to illustrate ways to motivate workers and eliminate costly disruptions in work flow. The authors acknowledge that while each case is unique, they believe these basic principles when applied 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 illustrates how proper training of the people in leadership positions directly over the laborers will result in increased labor productivity. This is due to the motivation of the 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 finds that properly trained supervisors have happier workers with higher motivation and productivity. It outlines a program designed to help supervisors more 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. This program is designed to help supervisors better match individuals with rewards. It gives different approaches to analyzing performance, keys for establishing realistic goals, planning of activities, matching workers to a task, and effectively coaching and communicating in order to identify the areas in which the personnel most need improvement (Hanna, Amir; 2001).

While conducting the literature review, two programs started at Departments of Transportation in different areas of the country identified favorable results in the motivation of their craft workers. These programs may provide information that could help the SCDOT increase their craft worker productivity and identify the best way to optimize their maintenance crews. Best of all, these programs have already been proven effective in similar types of work performed by the SCDOT. 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 is to create a workforce of highly trained workers across various skill levels, keeping NCDOT competitive in the market. The program promotes flexibility and equity in broad, generic job classifications that meet employees' and NCDOT's training needs. The program is built on "skill blocks" which are unique sets of tasks and duties selected as significant by each operating unit. These skill blocks are categorized as entry, intermediate, journey, and advanced levels. Each of the skill blocks is worth a set dollar value. Each skill block is achieved through a four-step process: testing, on-the-job training, certification, and compensation. In this system, employees advance through the four levels but remain in the same broad class of

Transportation Worker. The program has created enthusiasm among workers, and the workers drive the program (Aschbrenner, D.R., Domico, D. and Fountain, A.M.; 2000).

The second study gives a summary of the State of Oregon's Department of Transportation 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 even up to a year. The plan is then negotiated and agreed upon with the AMM. Each AMM has one area coordinator. The coordinator 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 were favorable and metrics used to measure worker productivity showed an improvement (Wilkins, S.; 1995). If desired, the SCDOT may want to look further into these programs and possibly adopt some of these procedures for their own craft workers. These programs demonstrate a relatively inexpensive and effective way to create enthusiasm and motivate workers. This should result in a noticeable increase in productivity among workers and may also show benefits such as reduced turnover rates and reduced 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 foremost books on the topic of construction labor motivation, this book is written with the premise that changing management techniques and operating procedures will improve on-site productivity. The data from the book comes from years of research by the authors. One of the primary points of the book

is that there is 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 inverse to the one 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, a worker, through his own efforts, produces a highly visible, physical structure in which great satisfaction can be derived from its completion. For instance, jobs that are well-planned and run smoothly produce great 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 with this productivity comes worker satisfaction. Other results include higher labor retention rates, a greater level of skilled workers and lower costs leading to higher profits. Additional areas addressed are safety and environmental health, and newer technologies (i.e. computers in 1989) and how they may be used in context with the practices in the book. While there are many different aspects to this book, the biggest example that can be applied to the optimization of maintenance crews in the SCDOT is that proper levels of communication and high levels of job satisfaction will show a significant increase in worker productivity. While this may seem to be a daunting task, even modest improvements in either of these areas will allow the SCDOT to look at the new level of

productivity being seen among their maintenance crews, and adjust their standards accordingly (using proper metrics). This will then 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 led the Research Steering Committee for this research 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 project duration. Progress reports were forwarded quarterly to the Research

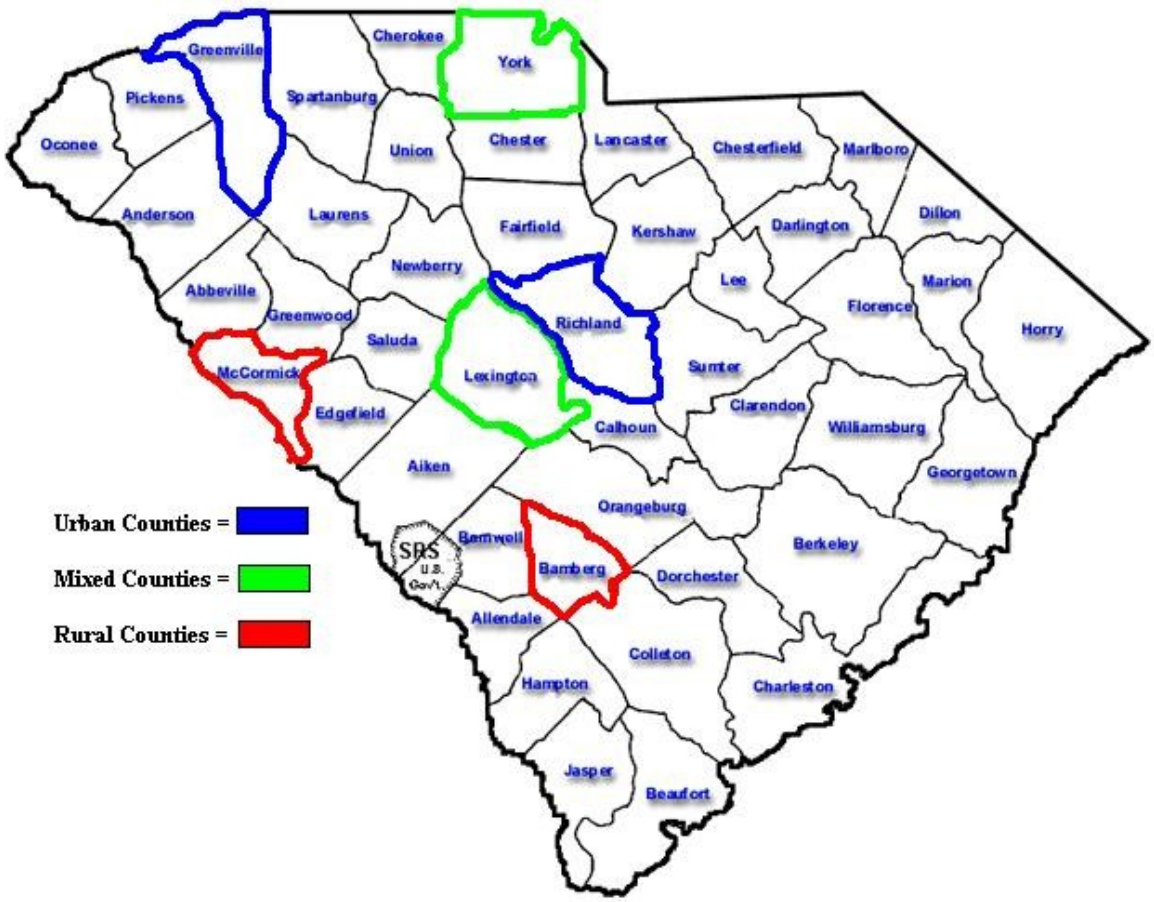
Committee in order to provide updates as to the progress of the research. During the course of the research, developments in the data findings led to meetings that changed the scope of the project considerable and narrowed the nature of the data analyzed. The data and feedback provided by the Research Committee was invaluable in finding the necessary information for the successful completion of the research at hand.

The SCDOT Highway Maintenance Management System was implemented to improve the utilization of resources for highway maintenance operations. This system is a statewide system that tracks data for all maintenance crews such as units accomplished, dollars spent, hours accumulated and equipment used for all tasks on a day to day basis. This data is stored in a database and is used to assist the SCDOT in its management of state highway infrastructure.

Data Analysis

In order to effectively analyze the immense 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 DOT engineers led to the selection of crews from three different types of counties – primarily urban, mixed urban and rural, and primarily rural. Upon recommendation from 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



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 was noted in the literature review, there are many different ways to analyze the performance of a crew. In order to best 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 were determined using these performance characteristics, the better performing crews were identified and their crew compositions noted. These better performing crews should 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 every crew across the six counties. Thus, a lower number indicates higher performance and a high number indicates poor performance.

The variations from 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 by a crew foreman. The Activity Composite Score was computed based upon crew performance for all work descriptions contained within each of these activities for a particular county type. The score is simply the average of the ranking achieved by each crew for all of the work descriptions in the county type in which they recorded a DWR. If a crew 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 great enough to be given an ACS. 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. Therefore, each crew can be compared based on their ACS to other crews within that county type, but due to the ranking orders cannot be compared to ACS values from other counties. For example, the rural county composite scores are lower than the ACS for the urban and mixed counties due to the fact that the rural rankings are based on a lower overall number of crews.

All crews were ranked based on the ACS and the top performing crews were determined for each county type. The crew size for each crew was plotted against the ACS to determine if better performing crews (i.e. those with a lower ACS) also represented a certain optimum number of workers.

An equipment optimization analysis was also performed using HMMS data gathered for the six counties analyzed. The equipment used by each crew for an activity is

recorded in HMMS daily. Examination of equipment usage over the three years of data provided allowed the research team to recommend changes to the equipment specifications by eliminating equipment that was not deemed necessary by the SCDOT. Eliminating equipment for a given work description that is not used greater than 50% of the time required for the activity would significantly improve the equipment optimization desired by the SCDOT. Tables were generated and organized by work description, crew, and county indicating the equipment recommended for each work description as well as the elimination of unnecessary units.

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 can be very beneficial. A survey was developed based on a survey conducted of skilled construction craft labor by CII in 2002 (Brandenburg, 2006) and administered on site at each of the county offices for the six counties in this analysis. The survey was designed to gather information pertinent to the analysis of the maintenance crew's performance characteristics across the state. Workers were asked to provide information to questions regarding their personal educational background, work experience, technical knowledge, opinions on the DOT, opinions of their crew and their individual performance. They were also given the ability to voice any suggestions or concerns they may have.

A total of 382 surveys were completed by maintenance workers and maintenance engineers. This data was compiled using a Microsoft Access database that will allow the SCDOT to easily retrieve and manipulate data. Some preliminary data analysis is included in this research

report, however, additional data analysis and survey collection could produce invaluable information to the SCDOT about 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 realizing potential indicators of successful individuals and the components of successful maintenance crews.

Data CD

In order to support the research work a large amount of data was collected and a tremendous number of tables and files were generated. The amount of data is very large and would represent significant printing and reproduction costs. An electronic copy of this information will be available as a Data CD that can be copied and distributed as needed. The index of files for the data CD may be found in Appendix F.

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 being 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	kMcCormic	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	Total	Total	Total
	$	$	$	Qty	DWRs	Emps	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 the activity that fiscal year. The labor column indicates the total amount of money paid to the crew for their labor. The material column indicates the amount of money spent on material 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 being performed. This column will have 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 employee's 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 work 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 will 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 being 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. The performance criteria for all crews in each of the six counties are available on the Data CD.

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. These rankings can be found on the Data CD. 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

County	Crew #	Cost/Emp	Rank by:		
			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 significant determination of performance.

To accommodate the variation in individual crew performance across the criteria, a crew performance index (PIN) was computed. 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 as 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 although for some performance criteria Crew # 70512 seemed to perform very well, it only ranked 26 overall out of a total of 61 crews. This makes it more of a middle-tier crew rather than a top performing crew. Bamberg County did have a top performing crew; Crew # 70515 was ranked fourth overall.

Many maintenance crews in the SCDOT specialize in one major type of 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. The complete ranking list of each of the major activities can be found on the Data CD.

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 many categories, would not provide a complete answer to 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 involves different units of measure making comparisons across the categories impractical. This analysis provides valuable data for the SCDOT in terms of performance measurements for maintenance crews; however it would

be necessary to examine a different measure of analysis in order to properly determine optimum crew configurations.

The initial analysis was presented to the SCDOT for review and based upon the results it was determined that analyzing the data based on work descriptions would produce more accurate results. 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 characterization of the work entered into the system. Each activity description includes different work descriptions. This 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 like units of accomplishment and thus, for each work description an optimal crew composition for each county type may be more evident. This should enable the SCDOT to develop more precise recommendations for crew size based upon the type of work being performed. 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**

The fiscal year column gives the years for which data was gathered and by which the crew was analyzed. 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 thus discarded. The table shows the costs incurred by the crew for labor, equipment, and materials for that 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 comparing performance by work description is that the units for work accomplished will 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 the 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 is 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 will allow the SCDOT to identify the top performing crews for each work description for each type of county.

The data organized by work description 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 could determine 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 Desc. 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 ranks lists the ranks derived from the different work descriptions within each activity in the cost per unit accomplished analysis for each crew. 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. In order to provide more statistically valid data any crew with less than three rankings within the activity description was not used in the analysis. Once the ACS was determined for each of the crews, an analysis of the configurations of these crews could indicate optimum crew configurations. It is anticipated that better performing crews within activity type and county category will have similar crew configurations.

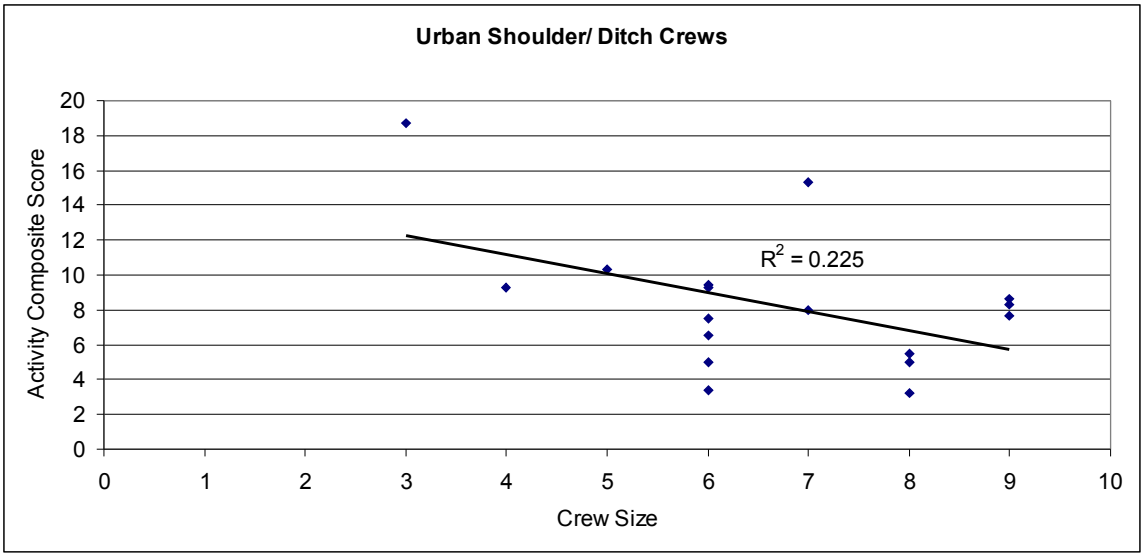


Figure 2: Crew Size and ACS for Urban Shoulder and Ditch Crews

From this plot, it is evident that there is a lot of variation in crew size for the 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 give some indication 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 and therefore there is no evidence to support the hypothesis that a crew's size can determine its performance. An R^2 value of 0.225 confirms this.

Figure 3 displays the correlation between crew size and ACS for mixed crews performing shoulder and ditch work and it becomes apparent that there is still no statistically significant correlation. It does appear that better performing crews tended to have only six crew members for this activity, although there was still a wide range of performance for this number of crew members. The sample size is still too small for a 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 more uniform analysis more difficult.

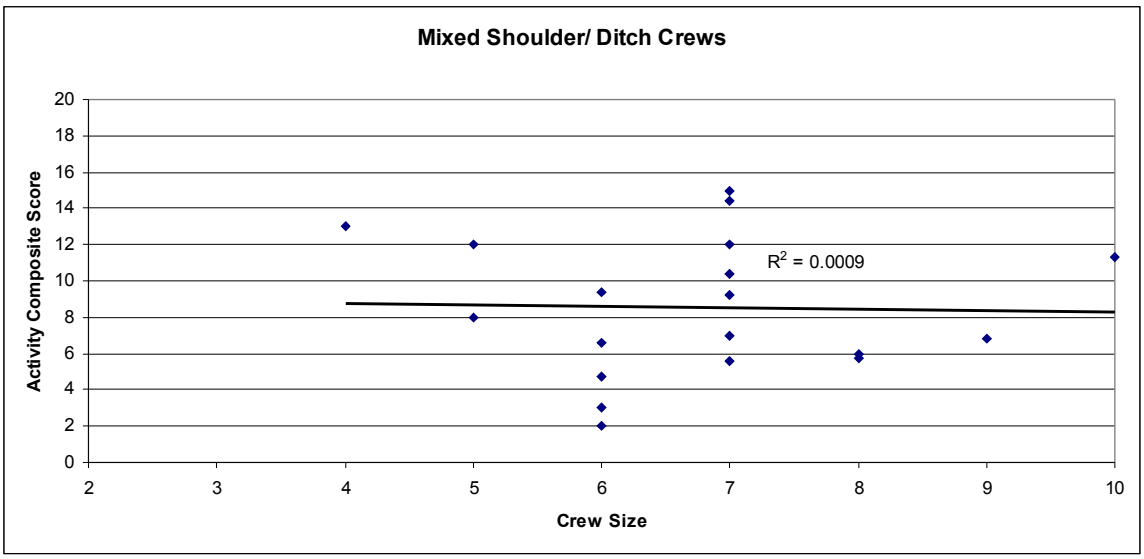


Figure 3: Crew Size and ACS for Mixed Shoulder and Ditch Crews

As can be seen in Figure 4, the ACS for rural crews were lower that those of other counties. This is due to the fact that there are fewer rural crews in the data sample. The ACS is calculated by averaging the work description ranks so if there are fewer crews in the ranks, a rank of 3 out of 7 would produce much lower ACS scores than a similar rank of 3 for the urban counties where more than 20 crews were evaluated. There is a limited data set for this category, but the best performing crew also had six crew members.

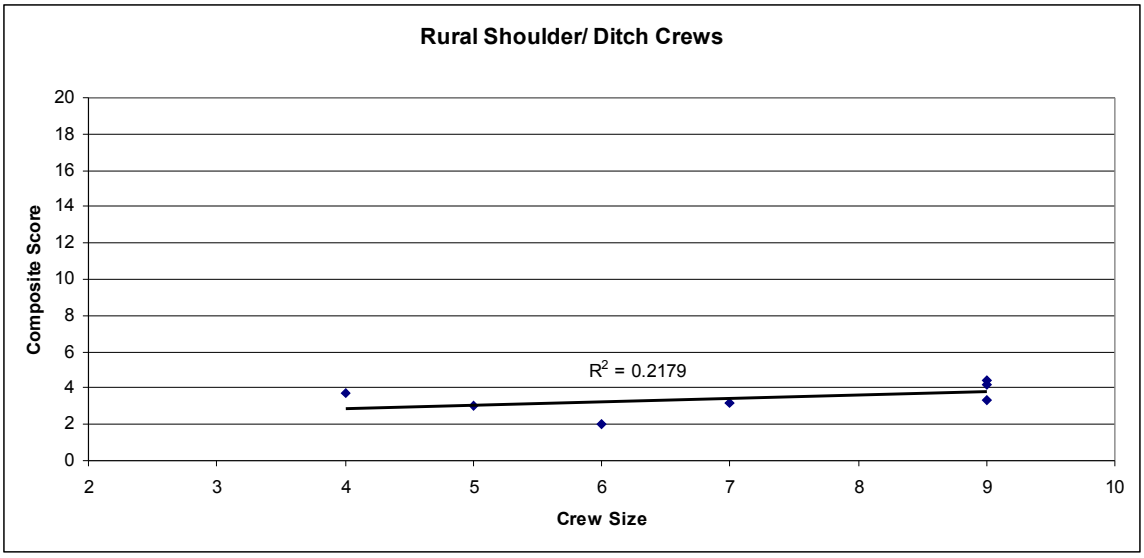


Figure 4: Crew Size and ACS for Rural Shoulder and Ditch Crews

A weighted composite score was developed to compare all crews across all county types, increasing the total data set to determine if there was a more accurate correlation between crew size and the composite score. The weighted score was computed using the county ACS divided by the highest possible ranking for that county. Figure 5 is a plot of the weighted composite scores for the shoulder and ditch crews and from the scatter it is evident that there is still no statistically significant correlation between crew size and composite score.

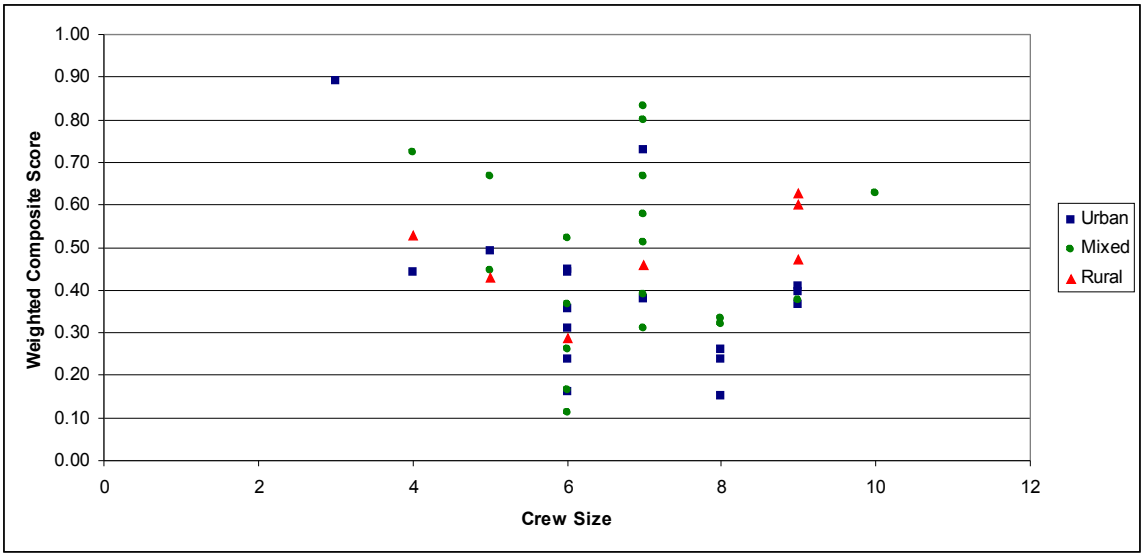


Figure 5: Weighted Composite Score for Shoulder and Ditch Crews

Crew size and composite score were also compared for surface repair crews, see Figures 6-8. For this activity there is too much variability to determine an optimum crew size. The best performing crew only had five crew 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.

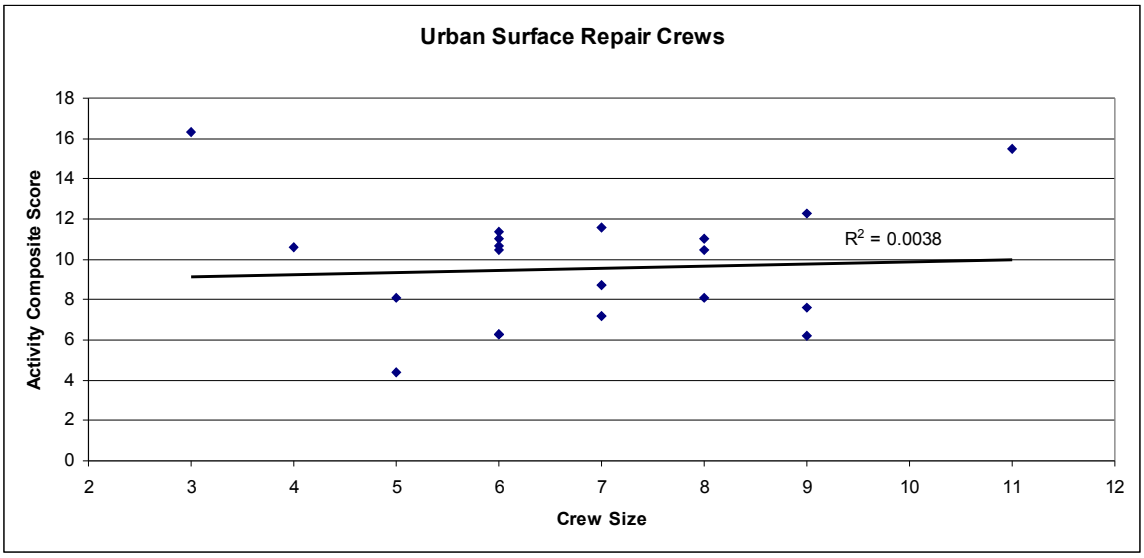


Figure 6: Crew Size and ACS for Urban Surface Repair Crews

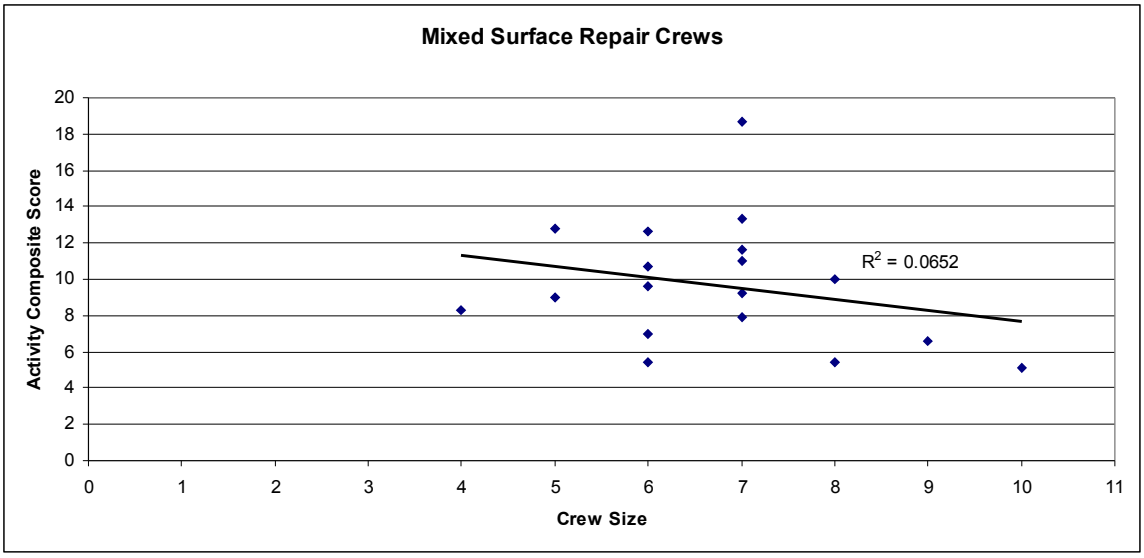


Figure 7: Crew Size and ACS for Mixed Surface Repair Crews

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 for a significant comparison and will not be analyzed by this method. The rural county crews are included in the weighted composite score plot as well as all of the crews for this activity (Figure 8). Again, there is no statistically significant correlation between crew size and composite score indicating that the performance of a crew may be too complicated to be determined by crew size alone.

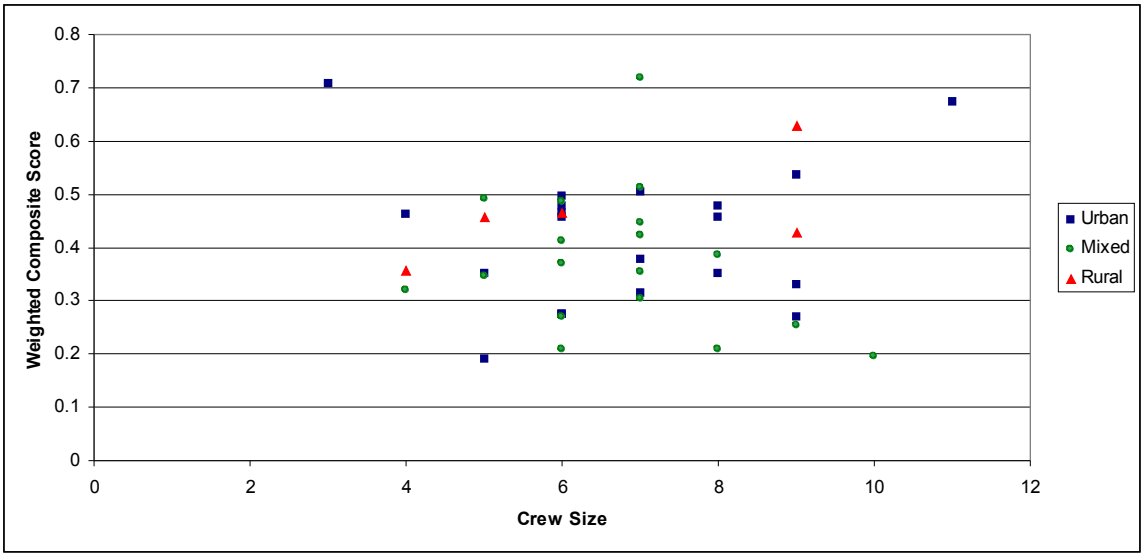


Figure 8: Weighted Composite Scores for Surface Repair Crews

As can be seen in Figure 9, the better performing crews in the urban counties for driveway work had either six or seven members. The performance of crews with eight and nine members appears to be not as productive. The sample size for this activity is simply too small to produce statistically significant data even though the correlation here is fairly high.

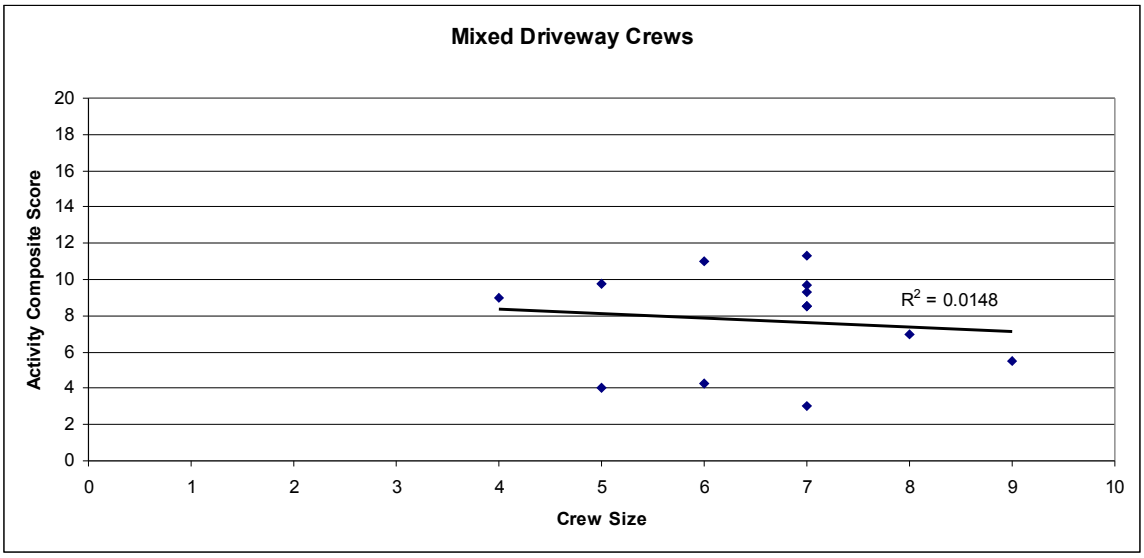


Figure 9: Crew Size and ACS for Urban Driveway Crews

There is also a lot of variation in performance of driveway crews in the mixed counties (Figure 10). 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 only includes five data points and is too small for even a basic analysis and will not be included in this report.

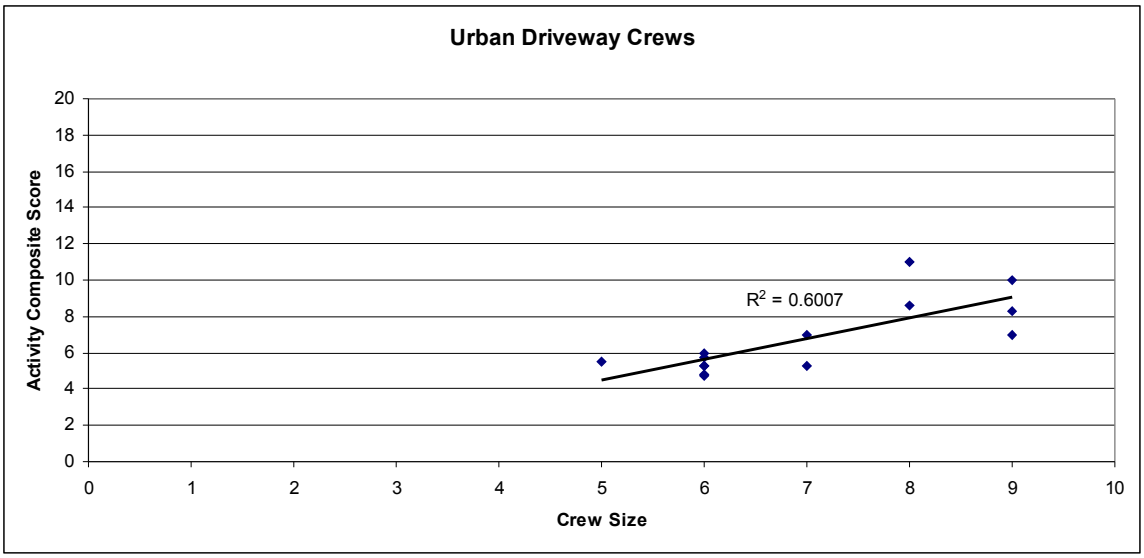


Figure 10: Crew Size and ACS for Mixed Driveway Crews

The weighted scores for the driveway crews are shown in Figure 11, and again there is just too much variation to use linear regression, or other similar regression techniques to determine the statistical correlation between crew size and performance.

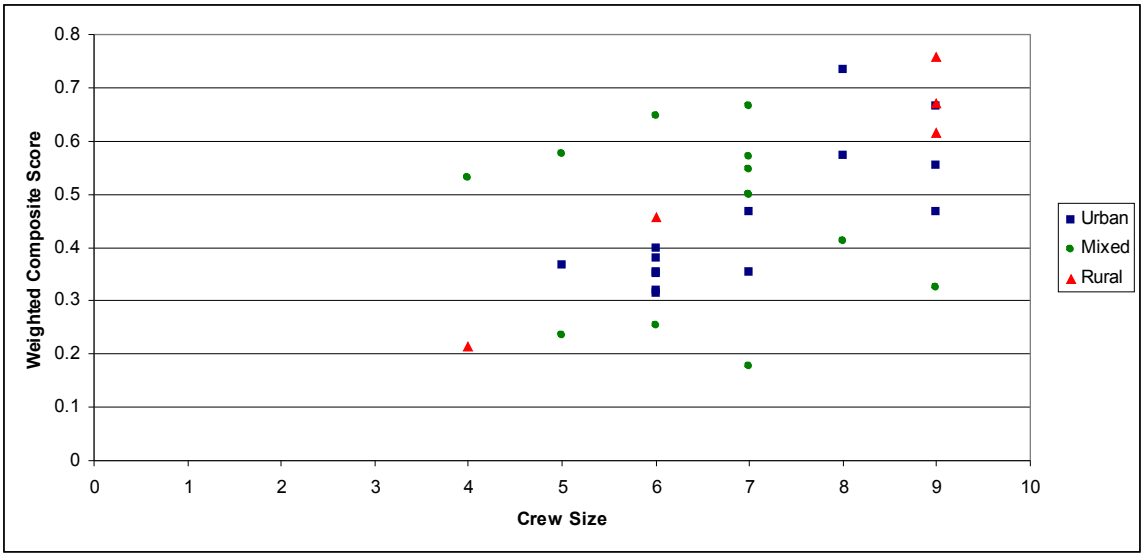


Figure 11: Weighted Composite Scores for Driveway Crews

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 does begin 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 that have been identified in this research be conducted to determine the specific characteristics of those crews and if they may represent an optimal crew configuration.

Equipment Optimization

The allocation and utilization of equipment for SCDOT maintenance crews can have a tremendous impact on the productivity and performance of those crews. The equipment used by each crew is recorded along with the other data entered into HMMS for a work description and has a profound effect on the performance of a crew. Examining the equipment usage by work description and identifying the most used equipment will allow for the SCDOT to adjust their equipment usage and 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 that activity. Those units are determined by equipment standards or specifications set for different activities at the state level. Certain types of equipment, however, 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 influenced the type of equipment chosen by a crew, including work conditions, the desire to hoard equipment with a particular crew, the quality of equipment, and equipment utilization rates. The equipment utilization rates determine the minimum amount of usage that a piece of equipment must receive annually as well as sets a minimum usage before a county may apply for a replacement or a new type of equipment. Certain units of equipment achieve their equipment utilization rate with ease while others do not. As a result, SCDOT engineers and crews make decisions on equipment selection for an activity based on current equipment utilization rates. Certain pieces of equipment may not

be the best suited for a particular job, but units may be selected simply to obtain 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. So, for this activity the ¾ 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 in 1 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 (which can be found on the Data CD) can be used by SCDOT to further refine their equipment recommendations and utilization rates for each work description. This should result in a more efficient usage of equipment thus boosting crew performance while decreasing the pressure placed on the resident engineers to reach equipment utilization rates.

In addition to quantitative data collected, interviews of SCDOT maintenance employees provided an interesting supplement to the data as well as anecdotal suggestions for improvements. While many different suggestions were voiced, there was one issue that came up again and again. This issue was equipment utilization. While many units of equipment are used often thus making required usage easy to attain, there are many units of equipment that are so infrequently needed that it is difficult to attain the required usage. Often equipment is assigned based upon 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. This survey is located in Appendix A. The average age of the SCDOT maintenance worker is 43 and Figure 12 shows the range of ages of these workers.

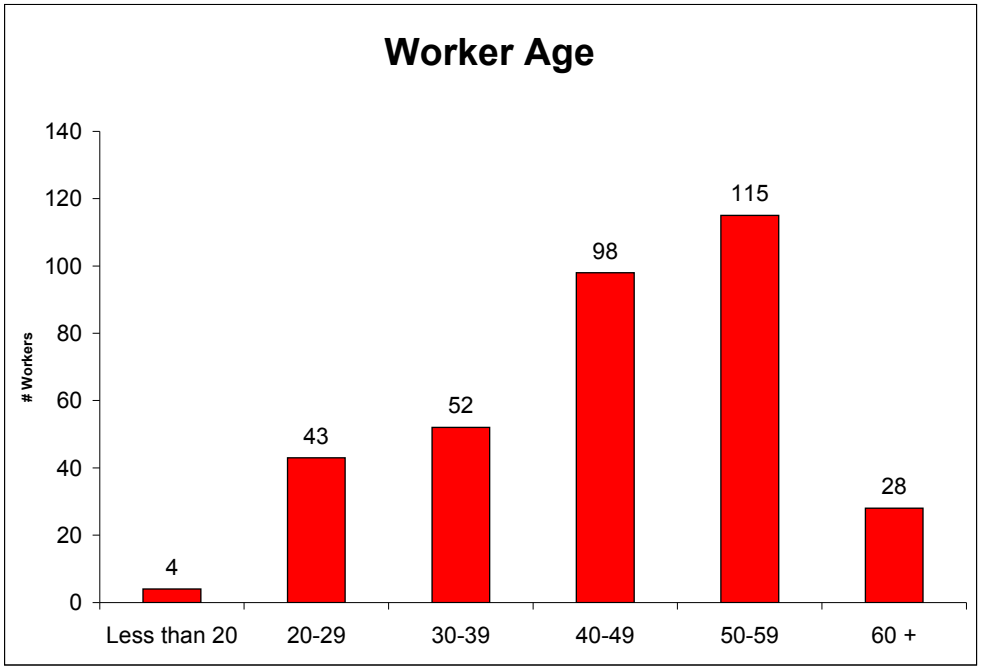


Figure 12: SCDOT Worker Age

Almost 10% of the workforce is female, a figure that is higher than the construction workforce in general which tends to only have about 2% of production occupations held by women. The SCDOT workforce is educated, with over 78% of the workers interviewed holding at least a high school diploma and almost 29% having 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 are clearly

understood by each crew's foreman. One question from the survey, Question 14, 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 crews.

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 is concerned with reaching these targets, only 68% of the foremen survey indicated the affirmative. There are a number of potential reasons for this answer. It could be that because the foremen believe the targets are realistic there is little concern about the crew's ability to meet them. Or, it could indicate a lack of motivation for achieving or exceeding the performance standards. The SCDOT may wish to consider tying performance achievement to a more effective incentive system which may contribute to increased productivity and improved performance.

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 could use more people. 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.

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 impact productivity. The workers survey 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

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 South Carolina maintenance workforce. Additional tables and figures, as well as the Microsoft Access Database are available on the Data CD.

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 posed 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. 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, however, these reports do not include all of the information that may impact a crew's performance to a greater extent than its crew size. For instance, traffic control problems are not recorded (notes may be made by a foreman as deemed necessary) and may have a drastic impact on work productivity and efficiency. It is speculated that a reduction in traffic control issues or congestion may be one contributor to the increased performance of some crews in rural or mixed counties.

What are the characteristics of the higher performing crews? That question cannot be answered satisfactorily by the data examined in this report. Crew size may only be one small component that impacts a crew's performance. Some other factors of higher performing crews may be experience, a good balance of experienced and inexperienced crew members, a strong foreman or resident engineer, a crew with more skills in multiple activities, good teamwork among crewmembers, etc. The literature has indicated that multi-skilled workers tend to be more productive (Castaneda et al, 2005). These are all factors that should be examined in more detail to effectively determine the criteria for developing better performing maintenance crews in South Carolina.

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 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.

It is believed that under-utilized equipment is often only used to obtain desired levels of equipment utilization and may not be the equipment preferred by the crew for the activity. 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 foreman 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, greater than 95%, reported knowledge of performance targets set for their crew. However, the statistic that should be of most concern to the SCDOT is that of the 56 foreman 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 foreman 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 been proven to provide incentives for the consistent performance for workers. One such program is the North Carolina Department of Transportation's skill based pay program. This program has yielded results and generated enthusiasm and higher levels of performance from its workers and may represent a program for which South Carolina may wish to analyze and perhaps replicate.

Recommendations

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 was 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. It is the recommendation of the research team that the top performing crews be studied in depth through additional surveys, interviews, and case studies to determine what are the characteristics of these crews that lead them to perform at a higher rate than other crews. An analysis of many of the rural crews would also be recommended due to the fact that most rural crews performed better than most crews on the same activity for urban or mixed counties. Once an in depth analysis of these top performers has been made, a metric for evaluating and developing crews for better performance could be established. As these characteristics are applied to other crews throughout the state in a field study, any improvements in productivity and efficiency could be measured.

The South Carolina Department of Transportation employs hundreds of maintenance workers each year whose productivity and performance are important to the overall efficiency of the Department. Effectively utilizing these employees and the equipment resources at their disposal are of critical importance. Optimizing crew configurations, while producing potential crew size recommendations for a few activities, did not determine a statistically significant correlation between crew size and performance. The SCDOT, however, can 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.

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

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

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

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

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

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

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

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

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

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

1	2	3	4	5
Strongly Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	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 RICHLAND - 4050 SECTION	KC20	TRADE SPECIALIST II	2A	2	9
		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

APPENDIX F

Index of Files for Data CD

Data CD Files

Folder	File Name	Type
Activity Rankings	All Rankings by PIN	Excel
	Crew Experience Statistics	Excel
	Crew Ranking Type	Excel
	Optimal Crew Statistics	Excel
Activity Reports	Activity Accomplishment- Clemson	Excel
	All Rankings	Excel
	Clemson Project Crew List	Excel
	Crew Data Unsorted	Excel
	Crew Sheets Sorted	Excel
	General Crew Data by County	Excel
	Ind Crew Performance Summary	Excel
	Weighted Costs and Accomplishment	Excel
Crew Survey Data	SCDOT Crew Composition Database	MS Access
	Final Survey	Word
	Survey Data	Excel
Mixed County Data	Clean Outfall	Excel
	Cleanup	Excel
	Construct Outfall	Excel
	Curb and Gutter Install	Excel
	Curb and Gutter Repair	Excel
	Driveway Install	Excel
	Driveway Move	Excel
	Driveway Paving	Excel
	Driveway Remove	Excel
	Driveway Repair	Excel
	Edge Patching by Hand	Excel
	Edge Patching with Machine	Excel
	Hand Trim	Excel
	Install Check Dam	Excel
	Minor Leveling by Hand	Excel
	Minor Leveling with Machine	Excel
	Pothole Patch by Hand	Excel
	Pothole Patch W Machine	Excel
	Regrade Roadside Ditch	Excel
	Regrade Shoulder	Excel
	Regrade Shoulder Ditch	Excel
	Repair Should	Excel
	Repair Shoulder (High)	Excel
	Resurface	Excel

Folder	File Name	Type
Mixed County Data	Routine	Excel
	Sidewalk Install	Excel
	Sidewalk Repair	Excel
	Widen Shoulder	Excel
Rural County Data	Centerline Machine	Excel
	Clean Outfall	Excel
	Cleanup	Excel
	Construct Outfall	Excel
	Curb and Gutter Install	Excel
	Curb and Gutter Repair	Excel
	Driveway Install	Excel
	Driveway Move	Excel
	Driveway Paving	Excel
	Driveway Remove	Excel
	Driveway Repair	Excel
	Edge Patching by Hand	Excel
	Edge Patching with Machine	Excel
	Minor Leveling by Hand	Excel
	Minor Leveling with Machine	Excel
	Pavement Markings Install	Excel
	Pothole Patch by Hand	Excel
	Pothole Patch W Machine	Excel
	Regrade Roadside Ditch	Excel
	Regrade Shoulder	Excel
	Regrade Shoulder Ditch	Excel
	Repair Should	Excel
	Repair Shoulder (High)	Excel
	Resurface	Excel
	Routine	Excel
	Sidewalk Install	Excel
	Sidewalk Repair	Excel
	Single Chip Seal	Excel
	Widen Shoulder	Excel

Urban County Data	Clean Outfall	Excel
	Cleanup	Excel
	Construct Outfall	Excel
	Curb and Gutter Repair	Excel
	Driveway Install	Excel
	Driveway Move	Excel
	Driveway Paving	Excel
	Driveway Remove	Excel
	Driveway Repair	Excel
	Edge Patching by Hand	Excel
	Edge Patching with Machine	Excel
	Hand Trim	Excel
	Install Check Dam	Excel
	Minor Leveling by Hand	Excel
	Minor Leveling with Machine	Excel
	Pothole Patch by Hand	Excel
	Pothole Patch W Machine	Excel
	Regrade Roadside Ditch	Excel
	Regrade Shoulder	Excel
	Regrade Shoulder Ditch	Excel
	Repair Should	Excel
	Repair Shoulder (High)	Excel
	Resurface	Excel
	Routine	Excel
	Sidewalk Repair	Excel
	Widen Shoulder	Excel

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