An Economic Evaluation Based on Total Cost of Aggregate Base vs. Asphalt Base

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16. Abstract

On the majority of highway projects let by the Florida Department of Transportation (FDOT), each bidder has traditionally been allowed to choose which base material they would use to construct the project if they were awarded the contract. The choice usually comes down to an aggregate (usually limerock) base vs. a hot-mix asphalt (HMA) base. When using only direct cost parameters, in most cases, the limerock alternative appears to be the most cost effective. However, some or all of the savings experienced in the purchase may be offset when considering total cost including road user and construction engineering and inspection costs.

This research effort attempts to develop a tool that compares the total cost of limerock base and HMA base. This tool, called a Cost Decision Tool (CDT), provides users with economic evaluations for limerock and HMA base options. The economic evaluation performed by the CDT will enable the FDOT practitioner to make a more reasonable and informed base material decision based on total cost/benefit parameters.

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CHAPTER ONE

1. INTRODUCTION AND RESEARCH METHODOLOGY

1.1 BACKGROUND AND PROBLEM STATEMENT

On the majority of highway projects let by the Florida Department of Transportation (FDOT), each bidder has traditionally been allowed to choose which base material they would use to construct the project if they were awarded the contract. This is accomplished by referring the bidder to the appropriate sheet in the FDOT *Flexible Pavement Design Manual* (FDOT, 2002b), where the different options are grouped according to the capacity provided to support the expected traffic loads as presented in Appendix A. In Section 5.5.2 of the manual, the contract specifies which group the bidder may choose from and each of the options within each group is designed to lend approximately the same support as measured by structural number. Any choice within the group is acceptable and it is incumbent upon the bidder to choose the option that gives it the best chance of success in the bidding process. In some cases, however, FDOT has called for a certain base type in lieu of the optional base concept. In these cases, the department has traditionally made its decision based on unit prices of materials, labor, and equipment.

While there are several options listed within a single optional group, the choice usually comes down to an aggregate (usually limerock) base vs. a hot-mix asphalt (HMA) base. In the past, deciding which alternative method to use was mainly based on a direct cost comparison based on unit prices of materials, labor, and equipment. When using only this direct cost parameter, in most cases, the limerock alternative appeared to be the most cost effective. However, many FDOT practitioners feel that other parameters need to be taken into consideration. Some of these parameters include the effect of rain, the length of time to complete the project, the effect on the business community, project location, as well as other parameters. An example provided by a contractor shows that limerock base material is less expensive but some or all of the savings experienced in the purchase may be offset by higher costs for excavation, MOT, installation, and finishing. This example is presented in Appendix B.

The FDOT needs comprehensive information to determine all the various parameters and to perform an economic evaluation of these two alternatives that will enable FDOT to determine the best alternative based on overall cost. Such an economic evaluation will enable the FDOT practitioner to make a more reasonable and informed decision based on total cost/benefit parameters.

1.2 RESEARCH OBJECTIVES

The objectives of this project are to develop, evaluate, and validate a model to determine which alternative (limerock base or asphalt base) would be the best choice economically, based on total cost. The economic evaluation between the two most popular base alternatives will enable the FDOT practitioner to determine the best alternative for a particular project based on total cost/benefit parameters.

When considering total cost, the length of time to complete the project is an especially critical factor in terms of cost-effectiveness. For example, if limerock base construction takes longer than that of HMA base, and as a result, the total project duration requires more time, the road user cost (RUC) of the project can become an important factor in determining a base option. In addition, longer construction time results in a higher construction engineering and inspection

(CE&I) cost. Therefore, taking RUC and CE&I cost into account, using limerock base may not always be the most cost-effective option. FDOT District Three (D-3) provides a graph for deciding working days of limerock base construction as presented in Appendix C.

Figure 1.1 illustrates a simplified concept of total cost comparison. HMA or limerock base option was assumed to be installed in the same area of a project to compare total costs. The total cost of both the HMA and limerock base construction consists of direct cost, RUC, and CE&I cost. RUC and CE&I cost are drawn as straight lines at the bottom of the figure. For most construction projects, RUC are expected to be much higher than the CE&I cost.

The direct cost of the HMA base option will be more expensive than for the limerock base option and this cost difference remains constant until the time when the HMA base option construction could be completed. Once the HMA base option is completed, the cost difference between the two options will be gradually decreased because the limerock base option incurs RUC and CE&I costs for a longer construction time. At a certain point in time, the total cost of the two options will be even and, after that point, the cost of the limerock option will be higher.

1.3 RESEARCH APPROACH

Work on this research consisted of accomplishing the following steps as illustrated in Figure 1.2.

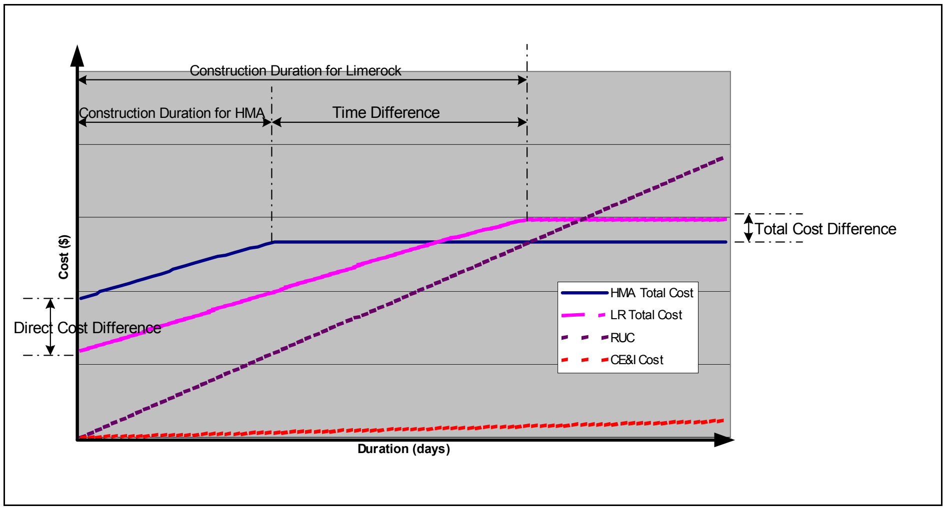

Figure 1-1. Concept of Total Cost Comparison

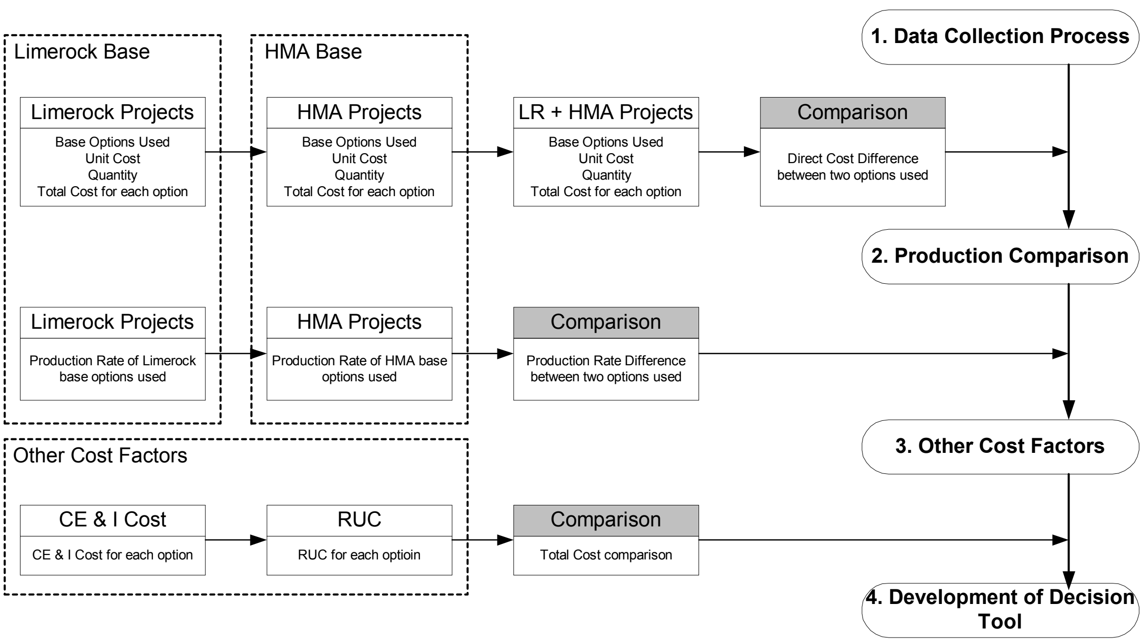

Figure 1-2. Research Methodology

1.3.1 Data Collection Process

The research team conducted a comprehensive data collection process. This data collection process included interviews, project visits, and project documents acquisition from the projects selected. Data was collected from three completed projects and three ongoing projects for each base option. The data collection process gathered project data for limerock and HMA bases including unit prices, quantities, direct costs of each option, individual workday quantities of work for the base item used, and the work hours of crewmembers and equipment. Production rates of base construction were measured thereafter. This data collection process is described in Chapter 3 in detail.

1.3.2 Production Comparison

The production rate of each base option was measured. The research team separated the method of data gathering and analysis based on project characteristics. For completed projects, project documents (daily diaries for limerock base and daily diaries and asphalt reports for HMA base) were obtained. Active projects provided more accurate information. For the active projects, a production measurement form was developed (Appendix D). The production measurement form was given to the project inspectors who filled in the information accordingly. This form contains such information as date of operation, lift constructed, quantity for each subtask, work crew and hours, equipment number and hours, and incidents. The information from the production measurement form was supplemented by daily diaries and, for HMA projects, the asphalt report. Accomplishing these tasks provided the research team with daily quantities of base construction for each workday. The production rates of the two options were then measured.

1.3.3 Other Cost Factors

CE&I cost and RUC were investigated since those cost factors are very important when comparing total cost. RUC has an especially significant impact on the total cost comparison. Therefore, RUC was studied in great detail as reported in Chapter 3.

1.3.4 Development of Decision Tool

After considering production rates and cost factors, an economic evaluation tool was developed. This result is presented in Chapter 6.

Reference:

Florida Department of Transportation. (2002b). *Flexible Pavement Design Manual.* Retrieved Jan 10, 2003, from http://www.dot.state.fl.us/PavementManagement/pcs/2002%20Flexible%20Pavement%20Manual.pdf

CHAPTER TWO

2. DATA ACQUISITION FOR BASE CONSTRUCTION

In order to make a proper comparison between limerock and HMA base options, the research required a comprehensive data collection process with regard to base construction production and cost issues. Therefore, the research team conducted an extensive data gathering process lasting over a year. The objectives of the data collection process were to collect data for computing production rates based on production output and input, comparing direct costs, computing other cost factors, and comparing total costs. The activities include:

1. Finding general information that has an impact on base construction including general characteristics of both options. Through interviews with practitioners, this information was obtained and is hereby described.
2. Finding projects that use limerock base, HMA base, or both.
3. Measuring the production rates of both options. This task called for devoted cooperation on the part of the inspectors to make project data available to the research team.
4. Comparing and computing the cost difference between the rates. Based on the result of this, the cost difference was computed and this difference was used for the total cost comparison.

2.1 GENERAL CHARACTERISTICS

The research team performed direct interviews with the various contractors, pavement designers, project inspection personnel, highway designers, and material testing personnel. As a result of these interviews, the characteristics of both base types were noted.

In FDOT District Two (D-2), the designer allows the FDOT Construction group decide which base type to use as long as the structural number is met. There is no definite policy as to when different base types can be called for, but some districts have memorandums with instructions and others do not. One such memorandum is shown in Appendix E.

According to the D-2 memorandum, "areas to consider for restricting the base course to asphalt is in urban areas on intersection improvement projects and reconstruction projects where, due to high traffic volume, expediting the construction of base material would be beneficial to the public." (FDOT, 1996)

Limerock base construction is known to take a longer time but has a lower initial cost than asphalt base as described. Some of the reasons for the longer construction time are listed below.

1. A Proctor test is required on limerock - not on HMA (typically takes 3-7 days per lift for two lifts)
2. Density must be achieved on each lift of limerock - only on the second lift of HMA
3. Rain can ruin limerock base and require reconstruction. Rain only delays the HMA operation until the surface dries.
4. Soil stabilization is required for limerock in the roadway, but not for HMA

Generally speaking, contract time is not altered depending upon which base is used even though estimates on time saved by using HMA base ranged from 15 - 50%. Typically, if they finish a paving operation early, contractors choose not to open the lane to the traveling public and FDOT doesn't shorten the project duration. However, D-2 does often change the contract time duration when calling for HMA base by adding the base quantity to the asphalt pay item and eliminating the base item completely. Since the prescribed formula for the calculation of time for the asphalt item differs from that for the base item, contract time may be reduced by this procedure. On projects of great physical length, the actual time for constructing the limerock base may not be very different from that for constructing a HMA base because the proctor process can be started immediately on the first lift and by the time the first lift of limerock is completed, the density for the beginning of the first lift can be approved so the second lift can be commenced immediately. Quality contractors have only minimal problems achieving density using either type of base.

2.1.1 Limerock Base

Limerock base is a good, affordable, local product and is improving in quality as excavators are getting past the lower-quality material near the earth's surface. The material first removed from most pits was described by one pavement designer as "similar to the material commonly used in fertilizers." Limerock has many advantages when it comes to direct cost-effectiveness. Most of those interviewed said that contractors are just as adept at placing limerock base as HMA base. However, it usually requires more time, as described.

The biggest advantage of using limerock base is a lower initial cost compared to asphalt base. Unless a contractor does not own a limerock pit and has to buy limerock from a competitor and transport it a long distance (hauling distance is a big factor in the cost of limerock), it is highly unlikely that limerock base will be more expensive to deliver to the project than HMA base.

The quantity of base required on a project can be a determining factor when deciding which base type to use. Huge quantities tend to sway designers to limerock even in an urban environment. One large project had an estimated $750,000 difference in base price between the two options.

Limerock is so much cheaper for some contractors that CW Roberts, a contractor with both a limerock pit and a HMA plant, regularly requests that he be allowed to haul any milled Recycled Asphalt Pavement (RAP) material off site and bring in limerock for shoulder construction instead of simply sweeping the RAP onto a shoulder and compacting it, a newly-approved method of shoulder construction.

The other major advantage to limerock base is that trucks can haul the material to the project and dump it at any time - even when the placing equipment and crew are not available. The material can be stockpiled on the roadway until the dozer, grader and compactor are available to place it. This allows the contractor to keep the other equipment busy performing other tasks until a prudent time to place the base material. Of course with asphalt base, all components of the paving train must work simultaneously.

Finally, according to the data obtained from the projects investigated and observations made, limerock base requires less labor to place than does asphalt base. On the other hand, there are indirect costs to using limerock base not present in HMA construction such as:

1. Barrier walls and other Maintenance of Transportation (MOT) items are needed for longer periods of time.
2. A Water truck is needed.
3. A Grader is needed.

Since trenches are cut deeper for limerock base construction and limerock base construction leaves the trench open longer than asphalt base construction, the safety factor is another disadvantage of using limerock base. In addition, since the cut for limerock is deeper, there is more material that requires disposal. Contractors know all the advantages and risks associated with limerock and almost always elect to take the risks and use it.

2.1.2 HMA Base

HMA base is generally preferred in cases of small projects such as intersections and in highly urban areas where it is politically unwise to delay opening a project to traffic. HMA is also good for dust and erosion control in urban areas. HMA base gives more flexibility for MOT, but often this is negated because the contractor elects not to use the lanes paved with base for this purpose.

If the weather is good, the timesaving for HMA is basically tied to the speed of the lab in getting proctor test results on limerock base to the constructor. In the Tallahassee area there seems to be less than a 10% time saving for HMA over limerock base because the labs are so quick to render proctor test results. This was the quickest time reported. From a quality control/ inspection perspective, asphalt base requires more inspectors than limerock base.

There were rutting problems in the past with HMA base, but things have improved since more emphasis was placed on the shape of the aggregate. However, there is no way to tell how the new SuperPave 12.5 mm base will perform as there is no past performance to analyze. Besides high traffic, urban areas and intersections, there is one other factor that can cause a designer to call for HMA base - the number of driveway connections. Use of HMA makes for simpler connections than does use of limerock. Use of HMA is good for the case of future milling and gives all concerned a "comfort zone" because once the first lift is down, weather ceases to be a major cause of concern. Table 2-1 shows the summary of the features for each base option.

Table 2-1. Summary of the Features for Two Base Options

Features / Base options	**Limerock Base**	**HMA Base**
Construction Time	Proctor test required More work hours	No proctor test required Fewer work hours
Cost	Low material cost Low initial cost High CE&I cost High RUC	High material cost High initial cost (Plant setup) Low CE&I cost Low RUC
Equipment required	Material delivery truck Dozer (or loader) Grader Water truck Roller	Material delivery truck Asphalt paver Roller
Safety factor	Lower	Higher
Constructability	Stockpiling possible	More flexible for MOT Good for dust, erosion control

The major advantages of HMA base are:

- "Water seal" effect of first lift
- Less MOT cost
- Lower inspection costs
- Higher Safety
- Potential earlier use of facility

2.2 PROJECTS INVESTIGATED

The research team sought for a long time to find adequate projects for data collection. It was especially difficult to find projects using HMA for base in sufficient quantities for proper analysis. When finding the projects, the PI made an initial visit to each in order to establish data collection protocol between the research team and project personnel.

The research team gathered data from three completed projects and three ongoing projects per each base option as shown in Table 2-2.

Table 2-2. Projects for Data Collection

	Limerock base	**HMA base**
Completed Projects	I-95 (Duval County)	SR 207 (Flagler County)
	Capital Circle	Capital Circle
	SR 500 (Alachua County)	US 441 (Alachua County)
Ongoing Projects	SR 26 (Alachua County)	SR 26 (Alachua County)
	SR 20 (Alachua County)	SR 20 (Putnam County)
	Jacksonville Airport Access Road	I-10 / I-110

2.2.1 Limerock Base

I-95, Duval County

- This project was completed before the start of this research project.
- Limerock base was used on this project

Capital Circle, Tallahassee

- This project was completed before the start of this research project.
- Two projects were constructed adjacent to each other during roughly the same time period by the same contractor. One of the projects used asphalt base and the other used limerock base. This was a unique and excellent opportunity to compare and analyze the two methods with a minimum of variables.

SR-500, Alachua County

- This project was completed before the start of this research project.
- Limerock base was used on this project.

SR 26, Alachua County

- This was an ongoing project
- There are both limerock and asphalt base components to this job, making it an extremely valuable one for this research. This was a unique opportunity to compare and analyze the two methods with a minimum of variables.
- The research team regularly visited this project. Visits were at least weekly. The data gathered on this project was exceptional. The CEI consultant, Jones, Edmunds, and Associates (JEA) graciously added a mailbox for the research team in their field office in Newberry. The project Engineer left all relevant data and information in the box for UF

personnel to pick up. Most weeks, the Project Engineer met with the students and took questions.

SR 20, Alachua County

- This is an ongoing project
- The plans for this project call for limerock base
- Base work began Mar 26, 2003 after a three-month delay. It was scheduled to start in December, but was delayed due to the illness of a key contractor employee.
- The CEI consultant, GAI, set up a data collection system based on the one used on SR 26.

Airport Access Road, Duval County

- This is an ongoing project.
- The plans for this project call for limerock base.
- This project was severely delayed. Base work was to begin on the first work day in January but actually started in April.

2.2.2 HMA Base

SR 207, Flagler County

- This project was completed before the start of this research project.
- Asphalt base was used on this project

US 441, Alachua County

- This project was completed before the start of this research project.
- Asphalt base was used on this project

SR 20, Putnam County

- This is an ongoing project.
- The plans for this project call for asphalt base.

I-10, Pensacola

- This is an ongoing project.
- The plans for this project call for asphalt base.

2.2.3 Timed Lane Closures

There are two distinct types of base construction projects that must be handled differently by agencies when they set out to determine the RUC for any construction project. Therefore, they were handled differently for purposes of this research.

- Lane widening/adding of paved shoulder

This type of project requires lane closures and RUC will be a larger factor. Stopwatch data is required on these.

- Road widening (adding lanes)

This type of project does not require lane closures. Therefore, RUC is limited to the before/after construction comparison.

Three projects were chosen for the timing of lane closures. An investigator visited the job sites and timed the traffic movements with a stopwatch several times. Then the investigator rode through the lane closure several times and noted the amount of time it took from the moment he started moving to the moment that the speed limit was achieved past the closure. Since RUC in the work zone with a lane closure is a very critical factor, more extensive research was conducted as reported in Chapter 3.

2.3 DATA COLLECTION PROCESS

Different data collection processes were employed for completed and active projects and limerock and HMA base construction. Table 2-3 shows the characteristics of base types. Data gathering requirements were determined by these characteristics.

Table 2-3. The Characteristics of Base Types

Base type	**Subtasks**	**Crew members**	**Equipment**
Limerock	Dumping Spreading Compacting	Foreman, Equipment operators, Labors	Material delivery trucks, loaders, graders, water trucks,
HMA	Spreading Compacting	Foreman, Equipment operators, Labors	Material delivery trucks, Asphalt paver, roller

2.3.1 Completed Projects

The data was collected after-the-fact for the completed projects with the research team visiting consultant and FDOT offices to obtain the project documents. The project documents included monthly or weekly estimates, daily diaries, and area computations.

The monthly/weekly estimate documents have the records of what work has been accomplished on a monthly or weekly basis. As shown in Appendix F, monthly/weekly estimates document such information as the item number, planned quantity, weekly/monthly increases in the cumulative quantity, unit price, and total price. These documents thus provided the total quantity and unit price for each base item. It was important to keep track of the quantity of base installed because occasionally daily diaries contained insufficient information to determine the daily quantity and it was very difficult to find the quantity after-the-fact. For the projects with limerock base, measuring actual quantity installed was not practical because the subtasks of limerock installation were often left unfinished at the end of the workday.

In the daily diaries, the inspectors recorded the base quantity by station numbers with the indication of the lift number. Limerock base installation is broken down into the subtasks of dumping, spreading, and compacting (or finishing), and each subtask may be accomplished on a separate day. In the documents, the inspectors specified the station numbers and work areas of each subtask separately. The station numbers were used to find the proper location in the typical section drawings or area computation documents so that paving widths could be obtained and the paving quantity calculated. For HMA base however, only the "placed" quantity with lift number was recorded because, even though HMA base installation requires subtasks of placing and compacting, the tasks were not left unfinished at the end of workday. Therefore, the construction managers easily measured and conveyed the quantity of HMA base installed on a daily basis.

In addition, the work hours were recorded in daily diaries by personnel and equipment. Crew hours recorded consisted of those for the superintendent, foreman, skilled laborer, semiskilled laborer, common laborer, and trainee of each crew. The number of each personnel type and their work hours were found from this source. The list of equipment used was also recorded in the daily diaries.

2.3.2 Active Projects

As described, the quantity measurement form was used for active projects. From the information in the form, the number of lifts required varies depending upon the base group where different structural requirements call for different thicknesses. When applying limerock base, the shoulder area usually has less thickness than the mainline because the mainline requires more structural strength. Thus, for the quantity input in the form, the thickness and width are separated by mainline and shoulder. As with the completed projects, the station numbers were specified so that the researchers could keep track of the project progress. This station number provides the geometric features when the plan document was looked to for a specific station number.

In addition, project documents of daily diaries and asphalt reports were procured by the research team for the projects with HMA base. Asphalt reports provided more accurate quantities on a daily basis than did the daily diaries. The research team could identify daily quantities by station numbers, number of loads, distance, width, area, and tonnage per base option and working day. An example of an asphalt report is shown in Appendix H.

Regular visits were also made by the research team to closely monitor project progress. If the form filled out by the project personnel contained ambiguous information, the research team asked questions to clarify the matter.

Reference:

Florida Department of Transportation (1996). Memorandum.

CHAPTER THREE

3. ROAD USER COSTS FOR HIGHWAY CONSTRUCTION PROJECTS INVOLVING A LANE CLOSURE

This chapter is a paper submitted for publication to the ASCE Journal of Construction Engineering and Management, December, 2003

3.1 INTRODUCTION

An important element in the prioritizing and planning of highway construction projects is the knowledge of how much the continued use of a substandard road in its present condition costs the users of the road on a daily basis. Another, related, element is how much of an economic impact that any construction proposed to standardize or improve the road might have on those same users during the life of the construction project.

While most State Highway Agencies (SHAs) have performed Road User Cost (RUC) calculations for many years, there is no formal uniform method of calculation being used nationwide. This leaves the states to follow their own processes or those developed by others (FDOT, 1997). Even less formal is the way different states handle the calculation of RUC when a lane must be closed during construction. The research team found almost no literature that actually employed a field study to validate any method. The purpose of this paper is to demonstrate an RUC calculation method employed by the state of Florida through four case studies in which lane closures in the work zone were necessary and compare the results to those obtained using a newer, automated method working with the same data.

For the purpose of calculating RUC, the Florida Department of Transportation (FDOT) uses "Techniques for Manually Estimating Road User Costs Associated with Construction Projects." This method was developed during a research project conducted by the Texas Transportation Institute (TTI) and sponsored by the Texas Department of Transportation

According to the method, RUC is defined as "the estimated daily cost to the traveling public resulting from road improvement work (construction work) being performed." The cost comes from time delays caused by various conditions such as:

< detours and rerouting,

< reduced roadway capacity,

< delay in the opening of a new or improved facility that prevents users from gaining a time benefit (TTI, 1999a).

From the field studies, the research team measured delay time caused by the reduced roadway capacity that was the result of lane closures.

The method categorizes four different conditions and utilizes different analysis approaches for each category. Both Table 3-1 and Table 3-2 were adopted from the method report. Table 3-1 explains the attributes of each analysis approach, and Table 3-2 describes the project type for each analysis approach.

FDOT uses the TTI method for the calculation of RUC, but they apply a unique value of time (VOT), which will be described later. With the field data collected, RUC was calculated by utilizing the FDOT method. Then, the project data was again used to calculate RUC using a commercial software package called MicroBENCOST, which was also developed by TTI. Finally, the results rendered by the two methods were compared.

Table 3-1. Attributes of Analysis Approach (TTI, 1999)

Analysis Approach	**Attributes**
Phase-by-Phase	The calculated user costs can be used as the basis for liquidated damages for milestone completions of each phase or selected phases of the project. This approach is most applicable to those projects with severe capacity restrictions during construction where phase completion time is critical.
Before vs. After	As opposed to a phase-by-phase approach, a "before and after" comparison of user costs focuses on the delay in final completion of a new or improved facility. Each day the final improved facility is delayed is another day that users are unable to realize travel time savings and other benefits from the additional roadway capacity.
During Construction vs. After	This approach is a combination of the two described above, and is applicable to projects where the final improvements do not result in an increase in capacity, i.e., rehabilitation projects. The during construction versus after approach compares the user costs associated with lane restrictions during construction against the user costs after the construction is completed.

3.1.1 Project Descriptions

The research team selected four ongoing projects in north-central Florida with lane closures and timed the traffic movements with a stopwatch. For the analysis of the projects by either method, the project must be placed into one of the categories shown in Table 3-2. The "During Construction vs After" approach was applied since the projects analyzed in this study all fell into the fourth category of "rehabilitation in a rural area" (Table 3-2).

The major difference between the methods used for "Before and After" and "During and After" is that while RUC for a typical project consists mainly of the difference in traffic flow before and after construction, a project involving a lane closure causes severe RUC *during* construction, and these costs must be included. The "During and After" feature takes these costs into account.

Table 3-2. Category of Projects for Application of RUC (TTI, 1999)

Category	**Description of Projects**	**Area**	**Analysis Approach**
I	Severe capacity reduction Critical completion time	Urban	Phase-by-Phase
II	Signalized/Diamond intersection	Urban	Before vs. After
III	Highway widening (not in I or II) New facility construction	Urban or Rural	Before vs. After
IV	Rehabilitation Non-capacity-added projects	*Urban or Rural*	During Construction vs. After

3.1.2 Project Category

Rural rehabilitation projects typically include lane widening, resurfacing, and adding of paved shoulder in rural areas. These types of projects usually require lane closures and, as a consequence, larger RUC occur during construction than for comparable projects without lane closures.

3.3.3 AADT

AADT is a determining factor when calculating RUC. It is defined as "the summation of the yearly volume of traffic divided by the number of days in the year" (AASHTO, 1977). Because the average duration of lane closure for the four projects was about ten hours per day, AADT was modified to reflect the actual time of lane closure by using the hours of daily traffic distribution as presented in the TTI method. Table 3-3 indicates hourly percentages of AADT during a 24-hour day (TTI, 1999a).

Table 3-3. Day Traffic Distribution (TTI, 1999)

Hour	% of AADT	Hour	% of AADT	Hour	% of AADT	Hour	% of AADT
1	1.8	7	2.5	13	5.7	19	5.5
2	1.5	8	3.5	14	6.4	20	4.7
3	1.3	9	4.2	15	6.8	21	3.8
4	1.3	10	5.0	16	7.3	22	3.2
5	1.5	11	5.4	17	9.3	23	2.6
6	1.8	12	5.6	18	7.0	24	2.3

Assuming that lane closure hours for a typical work day start at eight o'clock in the morning and end at five o'clock in the evening, the summation of the percentage of AADT during the lane closure will be 59.2 percent of the total Daily Traffic Distribution. Thus, AADT was adjusted by multiplying 59.2 percent (0.592) by the AADT, and the result is shown in Table 3-4 by "AADT (adjusted)." Table 3-4 illustrates the characteristics of the projects analyzed as part of this study.

Table 3-4. Project Characteristics

	SR-241	**SR-121**	**SR-100**	**SR-129**
County	Alachua	Union	Union	Levy
Project Category	Rural Rehabilitation	Rural Rehabilitation	Rural Rehabilitation	Rural Rehabilitation
Project Cost	$ 2.9 million	$ 3.6 million	$ 2.0 million	$ 2.6 million
Project Duration	236 work days	279 work days	260 work days	150 work days
Days of Lane Closure	170 days	100 days	90 days	70 days
Typical Hours of Lane Closure	7:00 AM - 5:30 PM	8:00 AM - 7:00 PM	9:00 AM - 4:00 PM	7:00 AM - 5:00 PM
AADT	7700	4700	5100	5200
AADT (adjusted)	4558	2782	3019	3078

3.2 TTI MANUAL METHOD

Using the "During Construction vs. After" approach, RUC is simply calculated by multiplying the delay time resulting from the work zone condition (closing a lane) by the value of time. RUC resulting from a work zone lane closure is calculated by Equation (3-1). Each of the terms in Equation (3-1) is defined and discussed in the sections immediately following.

$$\text{RUC} = \text{Delay Time} \times \text{Value of Time} \times \text{AADT (adjusted)} \qquad (3\text{-}1)$$

Where Delay Time = (Time with lane closure) - (Time without lane closure)

3.2.1 Delay Time

Delay time in each work zone was measured by timing delays in the work zone with a stopwatch. The experiment included ten visits to three projects (SR-241, SR-121, and SR-100) and four visits to SR-129. The data from one visit to SR-100 was removed because delay times were greatly increased by a traffic accident. These data were considered outliers. For each project, three or four visits out of ten were made in the afternoon, and the rest were made in the morning. Of the visits made to the SR-129 project, one was made in the afternoon.

During visits, the length of the lane closure was recorded due to variations in length based on conditions such as geometric features of the road and contractors' choices. The length of lane closures is limited to two miles by FDOT policy for safety reasons. Figure 3-1 illustrates the design of the delay timing experiment.

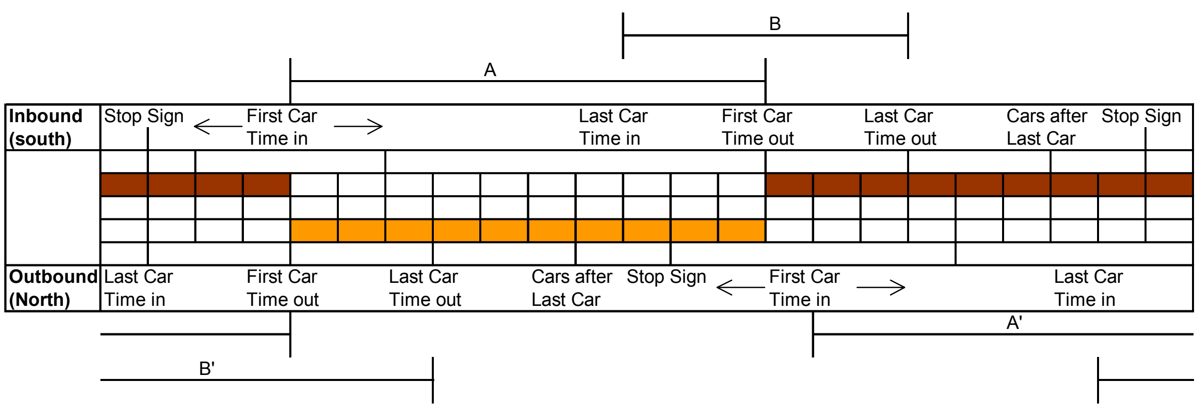

Figure 3-1. Design of Delay Timing Experiment

In Figure 3-1, the first car was stopped by the flagman, and its sitting time was measured (A). Then, the sitting time (B) of the last car (in a row) was measured. The number of cars in a row was counted and recorded in multiples of five. When the number was less than five, however, the exact number was recorded. By definition, the last car in a row always joined the line before the first car resumed travel through the work zone. The waiting times of the first car and the last car were averaged to determine the Average Waiting Time of cars in a row. Table 3-5 shows example data used to measure the Average Waiting Time.

The researcher then actually drove through the work zone during each visit in order to measure Average Driving Time. Because of time constraints and safety concerns, these measurements were done only a limited number of times (three or four times) per visit. The time measurement consisted of the time it took the driver to slow down, stop, wait, resume travel, and re-obtain the posted speed limit. Table 3-6 shows example data used to measure Average Driving Time.

It is important to note that the same waiting time and driving time were measured for travel in both directions based on the same directional AADT distribution. The researcher randomly measured waiting time at both ends of the work zone and confirmed similar results for traffic heading in both directions.

If work zone speed is defined as the distances traveled by each vehicle divided by the summation of travel times taken by each vehicle, then work zone speed was calculated and averaged as shown in equations (3-2) and (3-3).

$$\text{Work Zone Speed} = \frac{\text{Length of the work zone (distance of lane closure)}}{\text{Average Waiting Time} + \text{Average Driving Time}} \tag{3-2}$$

$$\text{Average Work Zone Speed} = \frac{\text{Sum of work zone speeds recorded}}{\text{Number of experiments}} \tag{3-3}$$

Table 3-5. Example Data for Measuring Delayed Time

Project:	**SR-241**	**Date:**	**11/22/02**
Lane Closure Distance:	**1** *mile*	**Running Time:**	**0.0428** *Hours*
Average Work Zone Speed:	**6.95** *mile/hour*		

Test Number	Time of Day	First Car Time out	Last car Time in	Last car Time out	Total Time Last Car	No. of car in a row	Waiting Time	Work Zone Speed (mile/hour)
1	7:26 AM	6:01	1:45	6:31	4:46	20	5:23	7.55
2	7:35 AM	9:37	3:14	10:07	6:53	20	8:15	5.55
3		9:37	4:34	10:26	5:52	30	7:44	5.82
4	7:51 AM	7:10	3:01	7:44	4:43	20	5:56	7.06
5		7:10	4:06	8:03	3:57	30	5:33	7.39
6	8:02 AM	8:51	3:01	9:21	6:20	20	7:35	5.91
7		8:51	4:24	9:41	5:17	30	7:04	6.23
8	8:15 AM	8:57	5:03	9:16	4:13	20	6:35	6.56
9		8:57	6:06	9:37	3:31	30	6:14	6.82
10	8:28 AM	5:22	3:09	5:54	2:45	20	4:03	9.07
11		5:22	3:39	6:10	2:31	30	3:56	9.23
12	8:37 AM	7:36	3:54	7:45	3:51	20	5:43	7.24
13		7:36	5:00	8:00	3:00	30	5:18	7.63
14	8:47 AM	7:12	3:22	7:37	4:15	20	5:43	7.24
15		7:12	6:30	7:54	1:24	30	4:18	8.74
16	8:57 AM	8:35	3:50	9:04	5:14	20	6:54	6.34
17		8:35	6:01	9:19	3:18	30	5:56	7.06
18	9:11 AM	8:55	3:47	9:19	5:32	20	7:13	6.13
19		8:55	5:52	9:39	3:47	30	6:21	6.73
20	9:22 AM	9:08	4:36	9:38	5:02	20	7:05	6.22
21		9:08	6:21	9:55	3:34	30	6:21	6.73
22	10:07 AM	9:02	5:44	9:29	3:45	20	6:23	6.70
23		9:02	7:20	9:48	2:28	30	5:45	7.21
24	10:19 AM	10:30	4:18	11:10	6:52	20	8:41	5.33
25		10:30	7:21	11:29	4:08	30	7:19	6.07
26	10:35 AM	7:58	1:57	8:10	6:13	10	7:05	6.22
27		7:58	6:10	8:15	2:05	20	5:01	7.91
28		7:58	7:58	8:35	0:37	30	4:17	8.76
29	10:43 AM	8:08	2:42	8:20	5:38	10	6:53	6.35
30		8:08	4:32	8:34	4:02	20	6:05	6.94
31	10:54 AM	7:57	1:41	8:13	6:32	10	7:14	6.12
32		7:57	5:58	8:35	2:37	20	5:17	7.64

Table 3-6. Example Data for Measuring Work Zone Driving Time

Test Number	Distance (mile)	Time of day	Time for Distance	Time to speed limit
1	1.00	9:35	2:43	2:57
2		11:13	2:25	2:58
Average Driving Time		28	2:34	2:57

In the first test shown in Table 3-5, for example, the Average Waiting Time of 20 cars in a row was 5 minutes and 23 seconds, and the Average Driving Time was 2 minutes and 34 seconds, which is shown in Table 3-6. By dividing the length of the lane closure of the day (1 mile) by the sum of Average Waiting Time and Average Driving Time, a speed of 7.55 miles per hour was calculated. Based on each work zone speed, an Average Work Zone Speed of 6.95 miles per hour was measured on that day.

3.2.2 Value of Time (VOT)

The American Association of State Highway and Transportation Officials (AASHTO) published "A Manual on User Benefit Analysis of Highway and Bus-Transit Improvement" in 1977, called the AASHTO Red Book. According to the manual, "a value is commonly placed on travel time savings by selecting a unit value of time and multiplying this unit value by the amount of time saved. The manual also mentioned that travelers are willing to make money expenditure in exchange for time saving" (AASHTO, 1977).

The manual takes vehicle operator cost, vehicle operating cost, and accident cost into account for VOT. For vehicle operator cost, the average hourly wage rate is multiplied by the number of adults per vehicle. The average wage rate must be updated based on changes in the Consumer Price Index (CPI) and may vary from place to place. The number of adults per vehicle depends on the trip type. Table 3-7 shows the example in the manual.

Table 3-7. Example of Adults per Vehicle (FDOT, 1997)

Trip Type	**Adult per Vehicle**
Work	1.22
Social-recreational	1.98
Personal business	1.64
Average	1.56

Vehicle operating costs include fuel, oil, tire, maintenance, and depreciation and VOT may also be updated by using the formula introduced in the AASHTO Red Book as shown in Equation (3-4) and presented in Table 3-8 (TTI, 1999a).

$$\text{VOT in question year} = \frac{\text{CPI in question year}}{\text{CPI in base year}} \times \text{VOT in base year} \qquad (3\text{-}4)$$

Table 3-8. Updating Value of Time (TTI, 1999)

Vehicle Type	Value of Time from 1990 ($/ hour)	Value of Time Adjusted to 1998 ($/ hour)
Small passenger car	$9.75	$12.16
Medium/large passenger car	$9.75	$12.16
Pickup/van	$9.75	$12.16
Bus	$10.64	$13.27
2-axle single unit truck	$13.64	$17.01
3-axle single unit truck	$16.28	$20.30
2-S2 semi truck	$20.30	$25.32
3-S2 semi truck	$22.53	$28.10
2-S1-2 semi truck	$22.53	$28.10
3-S2-2 semi truck	$22.53	$28.10
3-S2-4 semi truck	$22.53	$28.10

3.2.3 Example Using FDOT Method

FDOT basically uses the TTI manual method with a slight alteration in the calculation of VOT. In calculating the VOT, FDOT combines vehicle operator cost and operating cost, excluding accident cost because the expected accident rates may not change significantly after road improvement. The operating cost, however, is considered because the cost varies significantly depending on how much vehicle speed changes with the improvement. For example, the user cost per hour used by FDOT in 1995 was:

$ 8.55 : Average hourly wage rate of vehicle operator
+ $ 2.88 : Average hourly operating cost
$ 11.43 /hour /vehicle

This value, however, must be updated based on economic indicators (CPI) as described. The CPI of 1995 and 2003 are 139.1 and 157.2, respectively, so the VOT is converted by the formula shown in equation (3-5).

$$VOT_{2003} = \frac{157.0}{139.1} \times \$\,11.43 = \$12.92 \tag{3-5}$$

FDOT multiplies the derived VOT by the amount of time delay caused by the work zone lane closure. Some state Departments of Transportation apply the same method as FDOT except that VOT is multiplied by some factor that causes the result to better satisfy the needs of that agency. Illinois DOT, for example, multiplies the VOT by the average number of passengers per vehicle, which is 1.25 (FDOT, 1997).

3.2.4 Result From Field Studies

The results reported in this section were derived using the FDOT method described above. Table 3-9 shows the result of measurements for the four projects. Once work zone speed on a given day was averaged, the distance (length) of the lane closure was divided by the Average Work Zone Speed to calculate the time within the work zone. This is the "During" part of the "During vs. After" method.

The distance of the lane closure again was divided by the posted speed of the work zone area, and the time without the lane closure zone was calculated. This is the "After" part because a rehabilitation project (non-capacity added) usually results in no change in posted speed after construction. Posted speed may be increased, however, if the construction includes adding a paved shoulder. If this is the case, then the travel time without the work zone would be reduced, and as a consequence, the Daily Delay Cost would be increased.

Delay time is calculated by subtracting the travel time without the work zone from the travel time with the work zone. This value is multiplied by the VOT to derive the Daily Delay Cost per vehicle. Finally, multiplying the adjusted AADT to the Daily Delay Cost per vehicle provides a Total Daily Delay Cost. The Total Daily Delay Cost is summarized in Table 3-10.

3.3 MicroBENCOST APPLICATION

After calculating the RUC using the FDOT method, the RUC was recalculated using MicroBENCOST 2.0 software, and the results were compared. MicroBENCOST version 2.0 is a software for analyzing benefits developed by TTI (1999b).

Table 3-9. Result of Daily Delay Cost

Value of Time (VOT)	**12.92**	*$/car/hour*

Project	**SR-241**	(Alachua County)
AADT (adjusted)	**4558**	*car*

Date	Test No.	Distance (Mile)	Work Zone Speed (Mile/Hour)	Time with Work Zone (Hour)	Posted Speed (Mile/Hour)	Time without Work Zone (Hour)	Delayed time (Hour)	Total Daily Delay Cost ($/day)
11/22/2002	21	1	6.95	0.1439	55	0.0182	0.1257	$7,402.57
11/25/02	23	1	9.04	0.1106	55	0.0182	0.0924	$5,443.59
12/16/2002	15	1.2	10.15	0.1182	45	0.0267	0.0916	$5,391.91
1/6/2003	27	0.4	9.88	0.0405	45	0.0089	0.0316	$1,860.72
1/24/2003	18	1.2	10.21	0.1175	55	0.0218	0.0957	$5,636.52
2/4/2003	19	1	11.3	0.0885	55	0.0182	0.0703	$4,140.73
2/12/2003	33	0.8	11.72	0.0683	45	0.0178	0.0505	$2,972.83
2/19/2003	36	0.5	11.22	0.0446	55	0.0091	0.0355	$2,088.95
2/24/2003	35	0.6	14.07	0.0426	55	0.0109	0.0317	$1,868.84
3/14/2003	26	0.8	13.94	0.0574	55	0.0145	0.0428	$2,523.02
							Average Daily Delay Cost:	**$3,932.97**

Project	**SR-121**	(Union County)
AADT (adjusted)	**2782**	*car*

Date	Test No.	Distance (Mile)	Work Zone Speed (Mile/Hour)	Time with Work Zone (Hour)	Posted Speed (Mile/Hour)	Time without Work Zone (Hour)	Delayed time (Hour)	Total Daily Delay Cost ($/day)
1/10/2003	22	1.8	15.83	0.1137	55	0.0327	0.0810	$2,910.75
1/15/2003	16	1.4	15.33	0.0913	55	0.0255	0.0659	$2,366.89
1/17/2003	27	1.4	16.45	0.0851	55	0.0255	0.0596	$2,143.60
1/28/2003	21	1.4	16.52	0.0848	50	0.0280	0.0568	$2,040.53
1/31/2003	24	1.1	14.65	0.0751	50	0.0220	0.0531	$1,908.30
2/4/2003	23	1.3	12.62	0.1030	55	0.0236	0.0793	$2,851.83
2/14/2003	16	1.4	9.35	0.1497	55	0.0255	0.1242	$4,464.42
2/21/2003	24	1.6	19.83	0.0807	50	0.0320	0.0487	$1,749.31
2/26/2003	24	1.6	16.00	0.1000	55	0.0291	0.0709	$2,548.25
3/4/2003	28	0.7	17.37	0.0403	55	0.0127	0.0276	$991.02
							Average Daily Delay Cost:	**$2,397.49**

Project	**SR-100**	(Union County)
AADT (adjusted)	**3019**	*car*

Date	Test No.	Distance (Mile)	Work Zone Speed (Mile/Hour)	Time with Work Zone (Hour)	Posted Speed (Mile/Hour)	Time without Work Zone (Hour)	Delayed time (Hour)	Total Daily Delay Cost ($/day)
7/24/2003	16	1.1	12.27	0.0896	55	0.0200	0.0696	$2,716.71
7/25/2003	9	2.3	16.16	0.1423	60	0.0383	0.1040	$4,056.31
8/1/2003	9	2	14.1	0.1418	60	0.0333	0.1085	$4,232.51
8/11/2003	13	1.8	19.38	0.0929	60	0.0300	0.0629	$2,452.64
8/15/2003	33	0.4	13.22	0.0303	60	0.0067	0.0236	$920.16
8/19/2003	26	0.4	11.66	0.0343	50	0.0080	0.0263	$1,026.05
8/21/2003	23	0.8	13.17	0.0607	55	0.0145	0.0462	$1,802.00
8/28/2003	27	0.4	10.03	0.0399	50	0.0080	0.0319	$1,243.51
8/29/2003	22	0.4	10.82	0.0370	50	0.0080	0.0290	$1,129.93
							Average Daily Delay Cost:	**$2,175.54**

Project	**SR-129**	(Levy County)
AADT (adjusted)	**3078**	*car*

Date	Test No.	Distance (Mile)	Work Zone Speed (Mile/Hour)	Time with Work Zone (Hour)	Posted Speed (Mile/Hour)	Time without Work Zone (Hour)	Delayed time (Hour)	Total Daily Delay Cost ($/day)
3/21/2003	20	1.4	12.70	0.1102	55	0.0255	0.0848	$3,371.58
3/26/2003	17	1.7	15.33	0.1109	55	0.0309	0.0800	$3,179.88
4/4/2003	18	1.5	14.58	0.1029	45	0.0333	0.0695	$2,765.74
4/11/2003	11	1.7	11.97	0.1420	50	0.0340	0.1080	$4,295.78
							Average Daily Delay Cost:	**$3,403.24**

Table 3-10. Summary of Average Daily Delay Cost

Projects	AADT Adjusted	Average Daily Delay Cost
SR-241	4,558	$3,932.97
SR-121	2,782	$2,397.49
SR-100	3,019	$2,175.54
SR-129	3,078	$3,403.24

As mentioned, RUC for rehabilitation projects mainly comes from the user cost difference between "during improvement" with existence of a work zone and "after improvement" with no work zone. Figure 2 shows the structure of the MicroBENCOST (TTI, 1999b) that was applied to compute RUC.

In Figure 3-2, the RUC during improvement was first retrieved by inputting the appropriate information for the existing route in each category. This information includes work zone information in the Traffic Operation Category. Then, new values for the proposed route (after improvement) were entered, and the RUC for the new roadway was calculated. The difference between the two calculations was used to derive the user benefit value, which was used in calculating the daily RUC caused by the improvement.

3.3.1 Project Information

First, general project information such as area type, project type, and total construction cost was entered. "Area" is divided into rural and urban areas. "Project Type" has seven

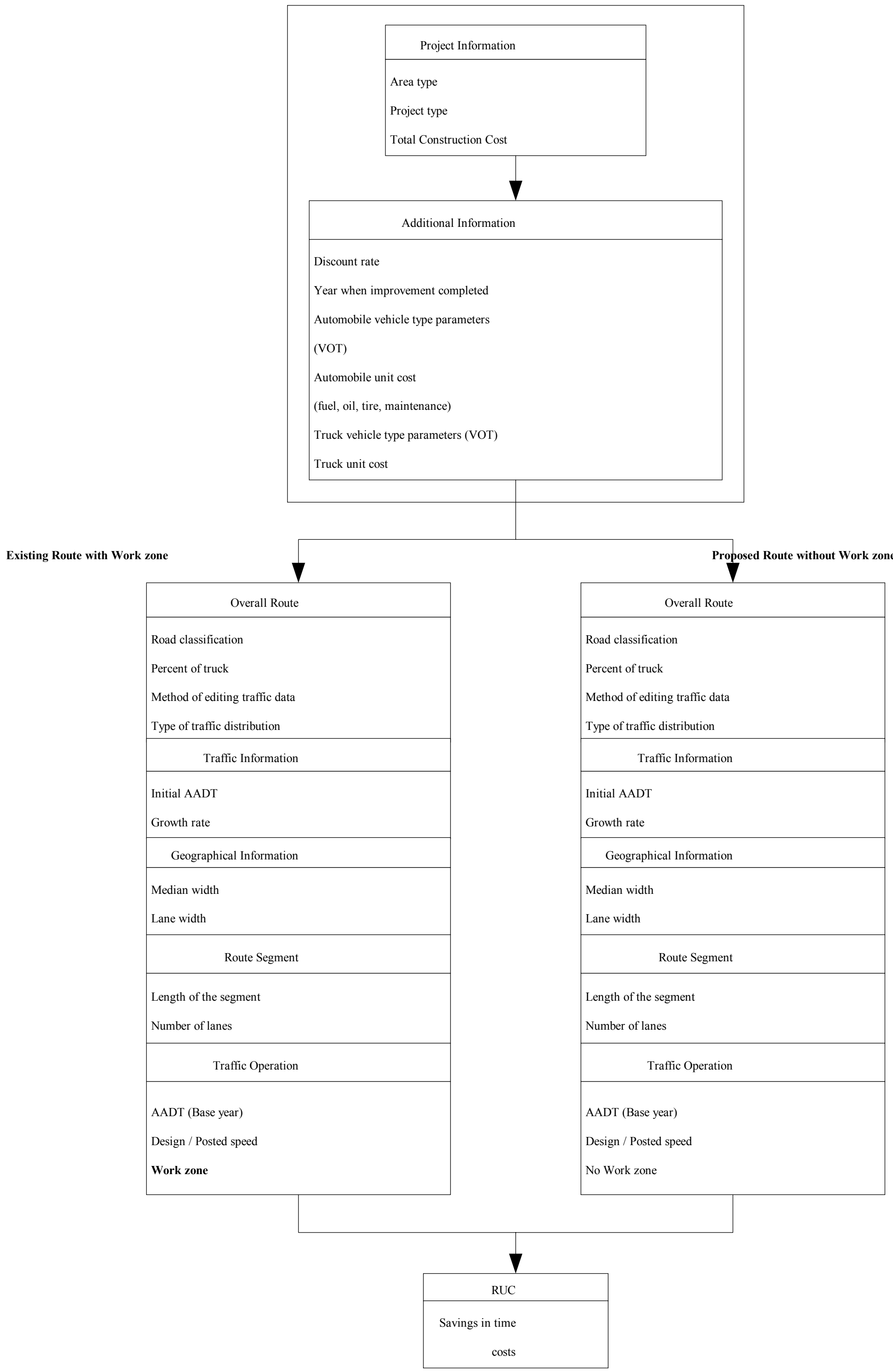

Figure 3-2. Structure of MicroBENCOST with Work Zone (TTI, 1999b)

options: added capacity, bypass, intersection/interchange, pavement rehabilitation, bridge, safety, and highway-railroad grade crossing. All of the projects selected for this study fall into the "pavement rehabilitation" category. "Total Construction Cost," another information field, is self-explanatory.

3.3.2 Additional Information

Additional information includes the discount rate, year of improvement completion, automobile vehicle type parameters (VOT), automobile unit costs (fuel, oil, tire, maintenance), truck vehicle type parameters (VOT), and truck unit costs.

Automobile vehicle type and truck type parameters (VOT) for the state of Florida are \$12.92 and \$22.36 for automobiles and trucks, respectively (TTI, 1999). Automobile and truck unit costs refer to the costs of fuel, oil, tire, maintenance, and depreciation. These costs are also adjusted to reflect current cost escalation.

3.3.3 Overall Route Information

Road classifications are consistent with roadway classifications defined in Chapter 334 of the 2002 Florida State Statutes. According to the statutes,

1. "Functional classification means the assignment of roads into systems according to the character of service they provide in relation to the total road network. Basic functional categories include arterial roads, collector roads, and local roads which may be subdivided into principal, major, or minor levels. Those levels may be additionally divided into rural and urban categories."

2. “Arterial road means a route providing service which is relatively continuous and of relatively high traffic volume, long average trip length, high operating speed, and high mobility importance. In addition, every United States numbered highway is an arterial road.”
3. “Local road means a route providing service which is of relatively low average traffic volume, short average trip length or minimal through-traffic movements, and high land access for abutting property.”
4. “Collector road means a route providing service which is of average traffic volume, average trip length, and average operating speed. Such a route also collects and distributes traffic between local roads or arterial roads and serves as a linkage between land access and mobility needs” (State of Florida, 2002).

For the percent trucks, the default value of 9.66 percent was applied. The method of editing traffic data allows the user to select from three traffic-forecasting methods: intermediate and forecast volumes, annual growth rate, and volumes for each year. Annual growth rate was applied from those options. The program presents two traffic distribution options. One presents AADT by the hour of the day and the other by the hours of the year. For this study, the research team chose to use AADT by the hour of the day.

3.3.4 Traffic and Geographical Information

Once the overall route data are entered, additional route information such as traffic and geometric information also can be input as needed. In the traffic information section, initial AADT, growth rate, and traffic distribution during the 24-hour time period are specified. For geometric information, the widths of medians, lanes, and shoulders can be specified.

3.3.5 Route Segment

The length of the segment and the number of lanes are decisive factors for the calculation of RUC for existing and proposed segments. The route segment data is specified in the traffic operation section. Here, design and posted speed were assigned based on the design of the road. Design speed was obtained from the typical section drawing in the construction documents.

Table 3-11. Input Data for SR-241

Data in Question	Value	Data in Question	Value
Area Type	Rural	Initial AADT	4,558
Project Type	Pavement Rehabilitation	Growth Rate	10 %
Total Construction Cost	$29,000,000	Lane Width	3.6 meter (12 feet)
Discount Rate	5 %	Shoulder Width	1.2 meter (4 feet)
Year when Improvement Completed	2003	AADT (Base year)	6,500
Road Classification	Minor Arterial	Segment Length	1.2 mile
Percent of Truck	10 %	No. of Work Zone	1
Method of Editing Traffic Data	Volumes for each year	No. of Days Work Zone in Place	236
Type of Traffic Distribution	Hour of Day	Beginning / Ending hour of Lane Closure	7:00 -18:00

Work zone information includes information such as the number of days the work zone is in place and beginning/ending hours of lane closure. Table 3-11 shows the input values for the SR-241 project as an example.

3.3.6 Results of MicroBENCOST

Table 3-12 shows the results of the MicroBENCOST analysis. As mentioned, Cost Benefit was calculated by subtracting the RUC of "After Construction" from that of "During Construction." The amount of Cost Benefit was then converted to daily RUC.

Table 3-12. Result of MicroBENCOST

Projects	During Construction ($)	After Construction ($)	Cost Benefit ($/year)	RUC ($/day)
SR-241	2,731,000	1,578,000	1,153,000	3,159.90
SR-121	1,495,000	798,000	697,000	1,910.59
SR-100	1,624,000	867,000	757,000	2,073.97
SR-129	1,656,000	884,000	772,000	2,115.07

3.4 DATA ANALYSIS SUMMARY

Table 3-13 is the summary of RUC for the four projects based on the information presented in Table 3-9. In both methods used, AADT was a determining factor in the calculation of RUC because the delay cost per car was multiplied by the AADT to calculate the total daily delay cost. Figure 3-3, which represents how AADT is related to RUC by using the FDOT method, shows that the volume of AADT is related to the amount of RUC. However, the RUC of SR-121 is higher than that of SR-100 in spite of a lower AADT. The reason is that the length of the lane closure on the SR-100 project was only 0.4 miles for four experimental days out of ten, and shorter distances cause smaller delays, resulting in lower RUC. Figure 4 shows that the MicroBENCOST application calculated an increased RUC as the AADT increased. This result validates the FDOT method because, as presented in Table 3-13, Figure 3-3, and Figure 3-4, RUC as calculated by the two methods were comparable.

Table 3-13. Summary of RUC

Projects	AADT Adjusted	Average Distance	Average Work Zone Speed	Posted Speed	RUC by FDOT (TTI Method)	RUC by MicroBENCOST
SR-121	2,782	1.37	15.40	54	$2,397.49	$1,910.59
SR-100	3,019	1.07	13.42	56	$2,175.54	$2,073.97
SR-129	3,078	1.58	13.65	52	$3,403.24	$2,115.07
SR-241	4,558	0.85	10.85	52	$3,932.97	$3,159.90

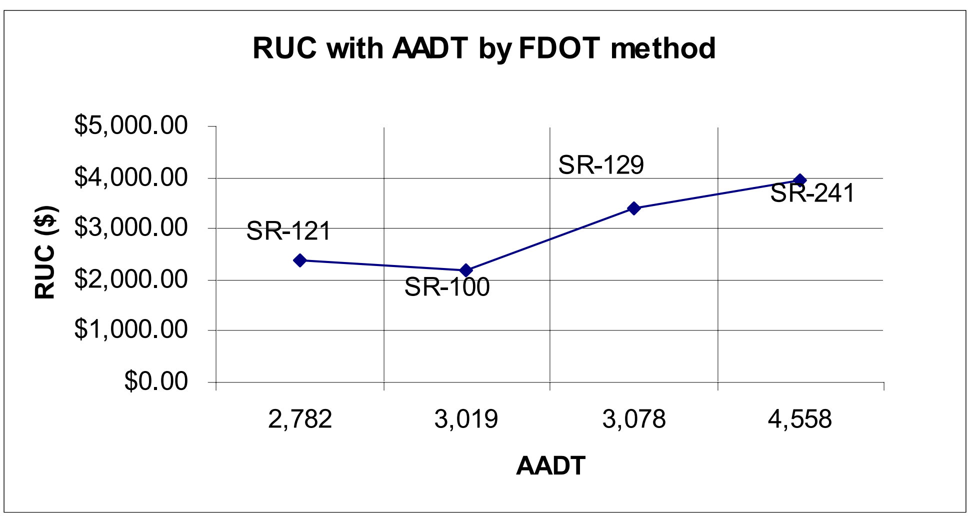

Figure 3-3. RUC and AADT by FDOT Method

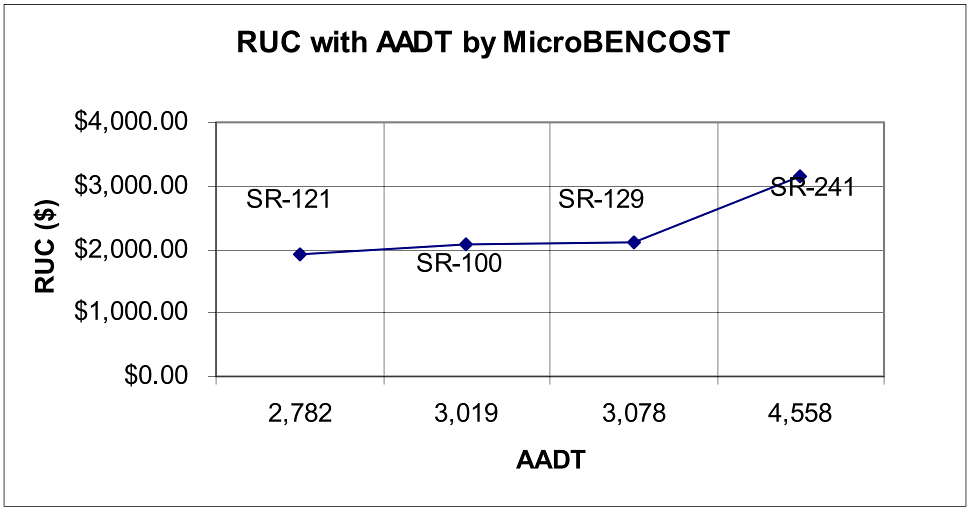

Figure 3-4. AADT and RUC by MicroBENCOST

Work zone speed does not appear to be directly related to RUC. Even though vehicle waiting time depends mainly upon the length of a lane closure, a long waiting time does not necessarily mean slow work zone speeds. Many factors that have no relationship to the length of the lane closure could affect the speed of traffic through a work zone. The work zone speed is compared to RUC in Figure 3-5. It is observed that the AADT is a far more important factor than the work zone speed when calculating RUC using either the customized TTI manual method employed by FDOT or MicroBENCOST.

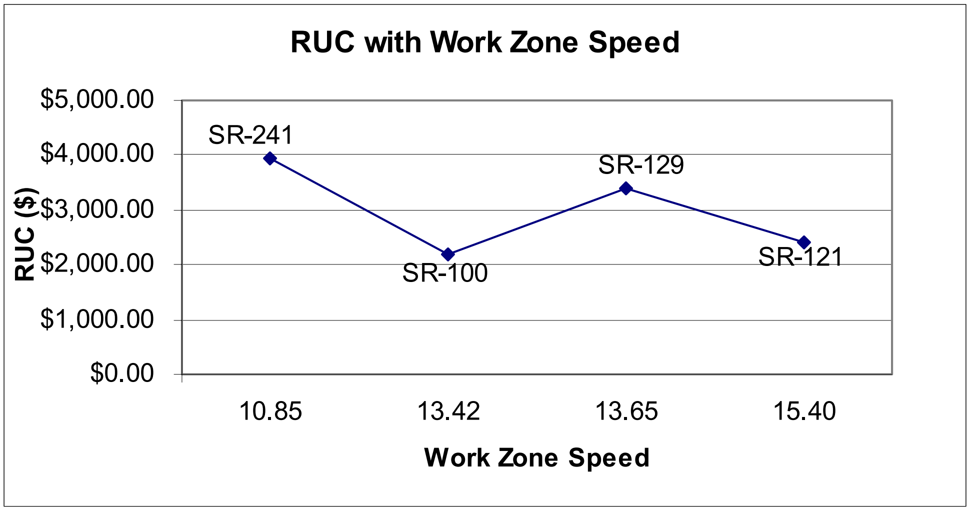

Figure 3-5. Relation between Work Zone Speed and RUC

3.5 CONCLUSION

The research team presented the actual field case studies in this report for the purpose of reporting the findings of the team in the calculation of RUC for projects with lane closures in the work zone and comparing two popular methods for this calculation.

Several factors contribute to RUC for any construction project involving lane closure. Among these are AADT, work zone speed, and length of lane closure, with the most important factor being AADT. The results proved that high RUC consistently occurs where high traffic volume (AADT) exists.

Because all four projects analyzed were rehabilitation projects in rural areas with less than 10,000 AADT, relatively small RUC values (less than $4,000 per day) were calculated using both methods (FDOT and MicroBENCOST). Using the same methods, however, the results would be completely different if the project analyzed were located in an urban area with a high AADT.

The two methods of RUC calculation used in this study yielded similar results; thus, either will yield satisfactory results when calculating RUC on highway construction projects with lane closures.

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CHAPTER FOUR

4. ANALYSIS BY TOTAL COST COMPARISON

With the data obtained, an analysis method was developed by considering the factors of cost information, production rates, RUC, CE&I cost, and total cost. In order to design the method, certain pieces of information discovered during the interview process were treated as assumptions. These assumptions include:

1. The direct cost of limerock base is almost always less than that of HMA base.
2. The production rate of limerock base is usually lower than that of HMA base.
3. Higher RUC and CE&I cost usually occur for limerock base construction than for HMA base.
4. The total cost analysis should take each of the facts listed above into consideration.

4.1 DIRECT COST COMPARISON

For the direct cost comparison, the unit prices that the successful bidders contracted for the base item were used because when the contractor submitted the unit price to the owner (FDOT), the price included all material and installation costs related to the base construction. As described in Chapter 2, when compared to HMA base, limerock base requires higher costs for excavation because a thicker base layer is required. Also, more work hours are needed for labor and equipment because of the complexity of subtasks. However, the unit price submitted by the contractor was calculated with those costs taken into consideration. Therefore, direct cost comparison by unit price takes all cost factors required for base construction into account.

The unit costs and quantities contracted are presented in Appendix I. In the table, total quantity and unit prices are identified based on each base item. Since the unit price of HMA base is more expensive than limerock base in the same optional base group, the direct cost difference within a single project can be computed by simulating the replacing of the quantity of limerock base with HMA. This is a scenario of "what if HMA had been used?"

In order to accomplish this scenario, the unit price of HMA for the same structural (optional) group of the limerock in use should be obtained from the historical data. However, this unit price may vary by project size (base quantity), project time, and project location. If the unit price of HMA within the same optional group is not obtained by historical data, it is calculated based on the structural number (SN) from HMA unit prices in other optional base groups.

According to Huang (1993), SN is a function of layer coefficients, layer thickness, and drainage coefficients and can be computed from equation (4-1).

$$SN_1 = a_1 \times D_1 \times m_1 \tag{4-1}$$

Where a= layer coefficient, D=layer thickness, m= drainage coefficient

FDOT assigns a unit structural number for each base material. For example, the unit SN of limerock base is 0.007 and that of HMA is 0.012 per millimeter. The SN of each base option is the unit SN multiplied by the thickness required. For instance, Base

Option Group 9 requires 260 mm-thick limerock base material to have a structural number of 1.82 by multiplying 260 mm by 0.007 while HMA base requires only 150 mm to get the equivalent structural number. If the HMA unit price for optional group 13 is available, the price is divided by 2.4, which is the structural number of Base Option Group 13. This renders the unit price per structural number. Then, the value is multiplied by 1.82 to get the equivalent unit price of HMA for Base Option Group 9. This is illustrated in Chapter 5 with data from project SR 26.

The next step is to decide the production rate of HMA base construction. The research team conducted statistical analysis to measure the average production rate of HMA base. Once the production rates of limerock base construction for three ongoing projects were measured, a calculation was performed where HMA base was assumed to be used in the limerock base area. The mean value of the HMA production rate was applied to calculate the production time and this process yielded a construction timesaving as a result of using HMA base instead of limerock. This production rate comparison is described in following section.

4.2 PRODUCTION RATE

The production rate of each option was computed from project documents and other forms given to the research team. The contents of the data were described in the prior section entitled Data Acquisition for Base Construction.

4.2.1 Production Input

"Crew Work Hours" and "Work Day" for base construction were considered the input values for the operation. The rationale of employing crew work hours for the input is that, even though both base operations are equipment-intensive, there was only one crew for the operation most of time, and this crew's hours include equipment operation hours as well. In other words, the crewmembers must have been working while the equipment was in operation. If the contractors employed more than one crew during a single workday, the crew hours were multiplied by the number of crews.

It is important to note that the crew work hours were adjusted in order to separate the crew work hours used only for base construction since the same crew could work for base, structural, and friction courses at different locations on the project on the same workday. The research team assumed that each lift of paving requires approximately the same number of work hours regardless of the course. For example, if the paving crew finished the first lift of base course and the first lift of structural course in different areas on the same workday, the actual area of base course completed was divided by the sum of the areas of base and structural courses in order to calculate an adjustment factor. Then, the crew work hours for the day was multiplied by the adjustment factor to derive the crew work hours for the base course.

Workday is another yardstick for measuring input quantity. The crew work hours per each working day were usually consistent, say, 10 hours per day. However, the contractor was sometimes faced with the situation that they had to stop working early. For example, afternoon rain is a regional weather characteristic and is one of the major reasons for the early stoppage. The other reason for early work stoppage was out-of-sequence work. For instance, if the contractor did not prepare enough subgrade, the base crew stopped placing the base course due to the work sequence.

For both limerock and HMA base operations, the research team recorded crew work hours for each working day and added all work hours and working days at the end of the data collection to calculate the average production rate. These input data include time for all subtasks performed for the base construction. In the end, however, it was decided that "work days" was not a reliable input measure for the purposes of this research and from that point on, all production calculations were made using work hours.

4.2.2 Production Output

In order to quantify production output for HMA base, the quantity of base was measured by square meters of surface area installed because base course is usually constructed in more than one lift. The number of lifts depends on the base option (thickness) as explained.

The other way to measure the output was calculating total lane miles when the job was completed. The lane mile measurement includes the mileage of all mainlines and turning lanes, but excludes shoulders. This method is valid only when comparing both base options without the production of shoulder areas.

4.2.2.1 Production output for HMA base

For HMA base construction, if the contractor completed a certain amount of area in a certain lift, the completed area is divided by the number of lifts required for the base construction. This value returns the surface area completed on a daily basis. This is the same way that the inspector measures the base bid item for payment purposes.

Since the research team obtained more accurate data from active projects than completed projects as explained in Chapter 2, three active projects of I-10, SR-26, and SR-20 (Putnam) were analyzed to calculate the average daily production rate of HMA base construction. The daily production rate of HMA was calculated by dividing the daily production output (surface area completed) by the production input (crew work hours) on a daily basis. This production data is shown in Appendix J.

After getting daily production rates and mean values of the rates from the projects, statistical analyses were performed to compare the production rates of HMA base construction for three active projects. The hypothesis of the analysis (H_a) is that the mean values of the production rates of three HMA base projects are not the same. If H_o cannot be rejected, the means are concluded to be the same.

$$H_o : \mu_1 = \mu_2 = \mu_3$$

H_a : Not all the means are same.

In order to compare three mean values, the required number of lifts must be the same since the production rate was measured and averaged by surface area completed. Even though the projects required different base options, three lifts were required for the construction as shown in Table 4-1.

Table 4-1 Summary of Active Projects with HMA Base

Projects	Optional Group	No. of lifts	μ (m^2/day)	Work days
I-10	11	3	171.8	34
SR-26 (Alachua)	13	3	134.7	49
SR-20 (Putnam)	15	3	122.3	12

Where μ =Average production rate

Before comparing the means, the normality test was performed by using Mini-tab software. The results are shown in Figures 4-1, 4-2, and 4-3. The x-axis of the graph indicates the daily production rate. The production rates of the three projects turned out to be normally distributed as shown in the figures. Then, the mean comparison was made in SAS statistical software. Table 4-2 shows the result of the analyses.

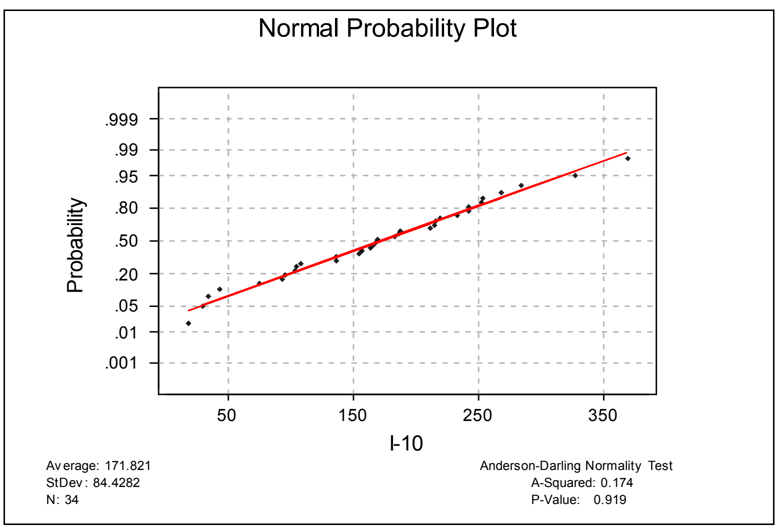

Figure 4-1. Normality Test for Production Rate (I-10 Project)

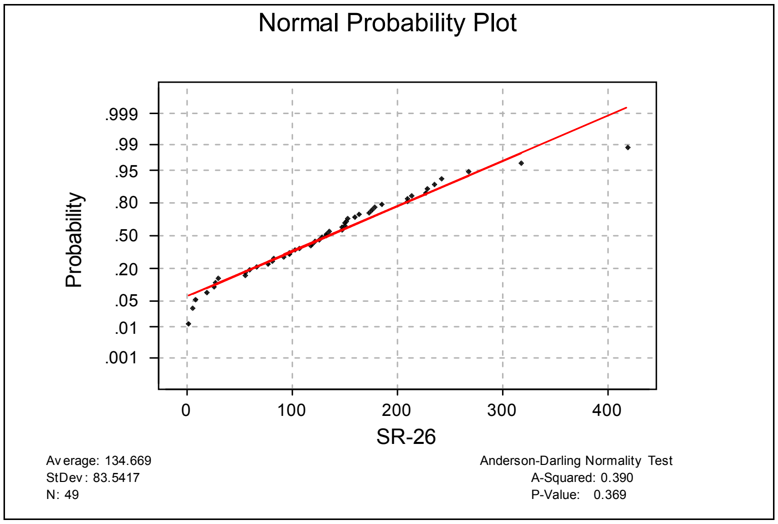

Figure 4-2. Normality Test for Production Rate (SR-26 Project)

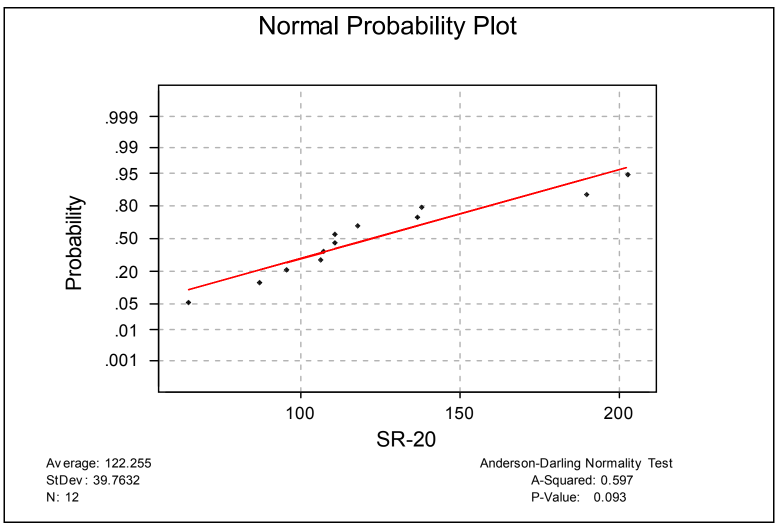

Figure 4-3. Normality Test for Production Rate (SR-20 Project)

Table 4-2. SAS Output for Comparing Four Means

General Linear Models Procedure					
Source	DF	Sum of Squares	Mean Square	F-value	P-value
Model	1	25439.91	25439.91	3.97	**0.0493**
Error	93	596002.02	6408.62	-	-
Total	94	621441.93	-	-	-

With a P-value of 0.0493 retrieved, H_o ($\mu_1 = \mu_2 = \mu_3$) could barely be rejected at the α = 5% level (0.05 > 0.0493), and the means could be concluded that at least two means are not same at the α = 5% level. However, because the P-value is very close to 0.05, Tukey's test was performed to further analyze the multiple mean comparisons as shown in Equation (4-2).

$$W_{(x)} = \frac{MSe}{n} \, q_{\alpha} \, (t, \nu) \tag{4-2}$$

Where, $W_{(x)}$ = Test Statistics
MSe = Error Mean Square
n = Number of Replications per Treatment (Working days)
t = Number of Treatment (Projects)
ν = Error Degree of Freedom

Since the value of n is not the same among the three treatments (projects), the value is calculated by Equation (4-3) as recommended (Miller, 1981).

$$n = \frac{t}{\frac{1}{n1} + \frac{1}{n2} + \frac{1}{n3}} \tag{4-3}$$

Where n1= 34, n2= 49, n3=12, t=3

In Tukey's Test, if the value of $W_{(x)}$ is larger than the difference between the mean values, the means can be concluded to be different. However, the value of $W_{(x)}$ was 57.01 in the test and the difference between the largest mean (172.8), and the smallest mean (122.3) was 50.5, which is smaller than $W_{(x)}$. Therefore, it can be concluded that all the means are equal at the α = 5% level. This result can be interpreted that, as long as the number of lifts were same, the production rates of the HMA bases were statistically consistent among the three projects investigated.

4.2.2.2 Production Output for Limerock Base

Daily output of limerock base construction was not measured the same way as for HMA base. As described, the subtasks of limerock base are not performed on a single workday. For example, the contractors dump limerock material on site (stockpile) on a workday and spread it on a later day. Then the contractor may compact the same area on various days (often the same area 3-5 times) in order to obtain the required density. Therefore, the research team measured total work hours and days of limerock construction and total quantity completed during the data collection time frame. By dividing the total output by the total input, the average production rate of the limerock construction was calculated.

In the SR-26 Project for example, total output of limerock base was 93,494.65 m^2, and the input was 1073 crew hours (CH). By dividing the finished area by crew hours, the production rate was measured as shown in Equation (4-4). The production rate was then 865.69 m^2/WD and 87.13 m^2/WH. The SR-26 project is described in greater detail in Chapter 5, entitled "Pilot Study for Economic Comparison."

$$\text{Production Rate of Limerock Base} = \frac{\text{Area Finished (m2)}}{\text{Work Hour}} \tag{4-4}$$

4.3 ROAD USER COSTS (RUC)

Calculations of RUC when the work zone requires a lane closure was described in Chapter 3. If there was a lane closure, RUC was very high and this cost went up significantly in an urban area with high AADT. Lane closure is usually required for rehabilitation projects.

The projects investigated with regard to base construction comparison fell into the category of "adding capacity". In "adding capacity" projects, the final completion of a new or improved facility reduces RUC significantly when compared to RUC of the existing road. Therefore, "each day that the final improved facility is delayed is another day that users are unable to realize travel time savings and other benefits from the additional roadway capacity" (TTI, 1999). RUC of "adding capacity" projects could be found in the TTI manual as introduced in Chapter 3.

4.4 CE&I COST

CE & I cost mainly depends on the hourly average wage rate of project inspection personnel and their time adjustment factor. The state of Florida statewide salary and wage rates were obtained (Appendix L) and from the wage rates, the time adjustment factor was assumed to be a portion of the time that the worker would spend on a single project. Table 4-3 shows the average wage rate and hourly CE & I cost respectively for a FDOT project.

Table 4-3. CE& I Cost

	Tile	CCEI Salary Rate	Adj. Factor	Cost
1	Senior Project Engineer	$ 38.76	5%	$ 1.94
2	Project Administrator	$ 31.71	10%	$ 3.17
3	Contract Support Specialist	$ 23.75	2%	$ 0.48
4	Office Manager	$ 16.41	2%	$ 0.33
5	Senior Inspector	$ 22.13	50%	$ 11.07
6	Inspector	$ 18.47	100%	$ 18.47
7	Inspector- Asphalt Plant	$ 19.58	100%	$ 19.58
8	Seceretary/Clerk	$ 13.65	5%	$ 0.68
Hourly CE & I Cost			**Limerock**	**HMA**
			$ 36.13	$ 55.71

4.5 ECONOMIC COMPARISON

Once the differences of direct cost, production rate, RUC, and CE&I cost were quantified, a total economic comparison was made. The research team conducted a pilot case study based on the SR-26 project, which used significant quantities of both base options in a single job, making the comparison both simple and relevant. This pilot study is presented in Chapter 5. With the data from the project, economic comparison was made based on the total cost.

From the pilot study, a cost decision tool was developed in order to apply the method to other projects as described in Chapter 6.

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CHAPTER FIVE

5. PILOT STUDY FOR ECONOMIC COMPARISON

5.1 GENERAL INFORMATION

Project SR-26 was selected for the pilot case study because there are large components of both limerock and asphalt base, making it an extremely valuable project for the comparison of base cost and production. The project involved adding two lanes to the existing two-lane road through rural Alachua County into the city of Newberry. The total project length was 8,097 meters (5.03 miles). The construction of both bases was started November 22, 2002 and completed on August 6, 2003.

The low bidder for the SR-26 project chose to use 100 mm (Base Option 1) and 260 mm limerock base (Base Option 9) in the rural part of the project and 200 mm HMA base (Base Option 13) for the urban section. Base Option 1 was used for the shoulder base only. General information for each base option is shown in Table 5-1. As explained, FDOT assigns a unit SN for each base material, and the SN of each base option is the unit SN multiplied by the thickness.

Table 5-1. SR-26 Base Description

Item Description	Thickness	Plan Qty	Unit	Unit Price	SN
Base Option 1 (Limerock)	100 mm	28,286.00	m^2	\$3.90	0.7
Base Option 9 (Limerock)	260 mm	69,424.00	m^2	\$7.20	1.82
Base Option 13 (HMA)	200 mm	45,418.00	m^2	\$18.60	2.4

5.2 DIRECT COST COMPARISON

FDOT limits the maximum thickness of a single lift of limerock base and HMA base to 200 mm and 75 mm respectively as shown below (FDOT, 2004).

> ***Limerock Base***
> ***200-5.2 Number of Courses:*** *When the specified compacted thickness of the base is greater than 6 inches [150 mm], construct the base in multiple courses of equal thickness. Individual courses shall not be less than 3 inches [75 mm]. The thickness of the first course may be increased to bear the weight of the construction equipment without disturbing the subgrade. If, through field tests, the Contractor can demonstrate that the compaction equipment can achieve density for the full depth of a thicker lift, and if approved by the Engineer, the base may be constructed in successive courses of not more than 8 inches [200 mm] compacted thickness.*
>
> ***HMA Base***
> ***234-8.1.3 Thickness of Layers****: Construct each course in layers not to exceed 3 inches [75 mm] compacted thickness.*

Therefore, limerock base in the shoulder area (Base Option Group 1, 100mm) was constructed with one lift while the base in the mainline area (Base Option Group 9, 260 mm) required two lifts. HMA base (Base Option Group 13, 200mm) required three lifts of HMA: 75, 50, and 75 mm. Figure 5-1 and 5-2 shows the typical section drawings of each base option.

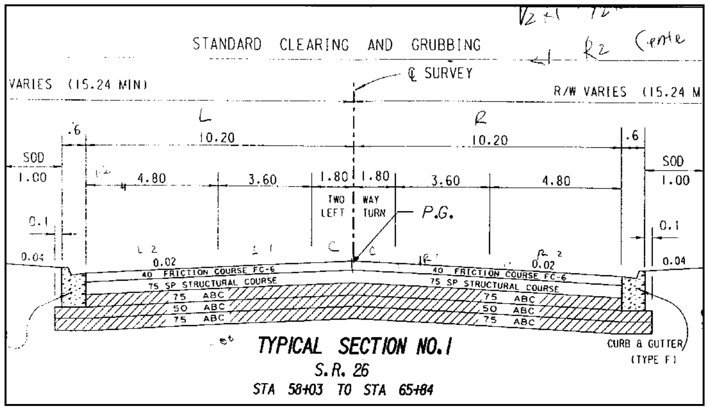

Figure 5-1. Typical Section for HMA Base

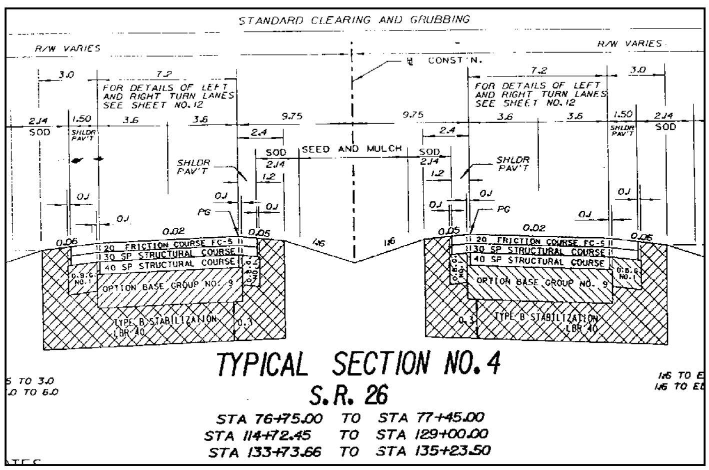

Figure 5-2. Typical Section for Limerock Base

Since the unit of measure for base options is square meters for this project, the varying base thicknesses makes the unit price difference between the two limerock bases. The unit price of HMA base (Base Option 13) was 477% and 258 % of the price of each limerock base respectively as shown in Table 5-1.

This comparison however is not a direct comparison because the strength requirement for the options in Base Option Group 13 is much higher than those for Base Option Group 1 or 9. The research team attempted, therefore, to obtain data from both

FDOT and industry sources on prices for the HMA options for Base Option Group 1 and 9 for comparison purpose. However, the search was unsuccessful. Even if those average prices had been found, they would not have been totally reliable for the purpose intended because prices vary greatly based on the unique characteristics of each project.

Therefore, the base price comparison was performed based on price per SN. By dividing the unit price by the SN, the price per SN can be calculated as shown in Table 5-2. Compared to the cost per square meter, the prices for the two methods are much more competitive when calculated by this method. The unit price per SN of HMA base is only 139 % and 196 % respectively over each limerock base. Base Option Group 9 is cheaper per SN than Base Option Group 1 even though it was almost twice as expensive when comparing unit price only. This is because the options in Base Option Group 9 provide much more structural strength than those in Base Option Group 1.

Table 5-2. Cost per Structural Number

Item Description	Item Number	Unit	Unit Price
Base Option 1 (Limerock)	2285701	$\$/m^2/SN$	\$5.57
Base Option 9 (Limerock)	2285709	$\$/m^2/SN$	\$3.96
Base Option 13 (HMA)	2285713	$\$/m^2/SN$	\$7.75

Base Option Groups 9 and 13 were compared since those two groups were used for mainline base. Because Base Option Group 9 requires a SN of 1.82, the unit price of HMA base for Option Group 9 will be \$7.75 multiplied by 1.82. This price thus will be \$14.11. If this unit price is used for the SR-26 scenario, the direct cost difference is calculated by Equation (5-1) below.

$$69{,}424\ m^2 \times (\$\ 14.11 - \$\ 7.20) = \$\ 479{,}719.84 \tag{5-1}$$

Where 69,424 m^2 = Area of limerock base (option 9)
$ 14.11= Unit price of HMA base (option 9)
$ 7.20= Unit price of limerock base (option 9)

5.3 PRODUCTION PARAMETERS

Table 5-3 below is the summary of the production rates of the two base types used on the project. Work hours were calculated as the input value and area finished was calculated as the output value.

Table 5-3. Productivity Parameters

Parameters \ Base Type		Limerock Base	HMA Base
Input	Work Hour	1073	406.7
Output	Lane Miles	11.2	7.8
	Area Finished (m^2)	69,424.00	47,544.52
Production Rates	Work Hours / Lane Mile	95.80	52.23
	Area Finished / Work Hour (m^2)	64.70	116.9

By definition, the production rate is calculated by input divided by output or output divided by input. Therefore, two production parameters were calculated - Work Hour per Lane Mile and Area Finished per Work Hour. Lane Mile is the length of all lanes including turning lanes.

Work Hours per Lane Mile of the limerock base was 95.80 while that of HMA base was only 52.23 hours. Area Finished per Work Hour values were 64.70 for the limerock base and 116.90 for the HMA base. Hence, the production rate of HMA base is by the two measures 183 % and 180 % that of limerock base. In order to compare the two base items homogeneously, the total area finished of each was divided by the total work hours to calculate the HMA base production rate in Table 5-3. The value 116.9 m^2/hour was different from 134.7 m^2/hour, which was calculated earlier by simply averaging the daily production rates of HMA base construction (This value was used to compare the means of HMA base construction across three projects as described in Chapter 4).

5.4 RUC AND CE&I COSTS

As described in Chapter 3, the final completion of a new or improved facility reduces RUC significantly when compared to the RUC of the existing road in adding capacity projects (TTI, 1999). For instance, completion of the SR-26 Project will reduce RUC significantly after adding two lanes to the existing two-lane road. Therefore, RUC is calculated by subtracting RUC_P (proposed condition) from RUC_e (existing condition). Table 5-4 shows the RUC for adding capacity.

Table 5-4. Example of RUC for Adding Capacity (TTI, 1999)

Two-Lane Rural Highway (0%-25% No Passing Zones) (In $/day per mile)				
ADT	5% trucks	10% trucks	15% trucks	20% trucks
5000	1,400	1,400	1,500	1,500
7500	2,100	2,200	2,200	2,300
10000	2,800	2,900	3,000	3,100
12500	3,600	3,700	3,800	3,900
15000	4,400	4,500	4,600	4,700
17500	5,200	5,300	5,500	5,600
20000	6,000	6,200	6,400	6,500
22500	7,000	7,200	7,400	7,500
25000	8,000	8,300	8,500	8,700
27500	9,300	9,600	9,800	10,100
30000	10,700	11,000	11,200	11,500
32500	12,300	12,600	12,900	13,200
35000	14,000	14,400	14,800	15,200
37500	16,100	16,500	16,900	17,400
40000	18,300	18,800	19,300	19,800
42500	20,700	21,200	21,800	22,400
45000	23,300	24,000	24,600	25,200
47500	26,000	26,700	27,400	28,100
50000	28,800	29,600	30,300	31,100

Four-Lane Rural Divided Highway (In $/day per mile)				
ADT	5% trucks	10% trucks	15% trucks	20% trucks
5000	1,400	1,400	1,500	1,500
7500	2,100	2,100	2,200	2,300
10000	2,800	2,900	3,000	3,000
12500	3,500	3,600	3,700	3,800
15000	4,200	4,300	4,500	4,600
17500	4,900	5,100	5,200	5,300
20000	5,700	5,800	6,000	6,100
22500	6,400	6,600	6,700	6,900
25000	7,100	7,300	7,500	7,700
27500	7,900	8,100	8,300	8,500
30000	8,700	8,900	9,100	9,400
32500	9,400	9,700	9,900	10,200
35000	10,200	10,500	10,800	11,000
37500	11,000	11,300	11,600	11,900
40000	11,800	12,200	12,500	12,800
42500	12,700	13,000	13,400	13,700
45000	13,500	13,900	14,300	14,600
47500	14,500	14,900	15,300	15,600
50000	15,400	15,800	16,300	16,700

The AADT of this stretch of SR-26 was 12,500 in the year 2002 (FDOT, 2002c). In Table 5-4, RUC_P and RUC_e were $3,600 and $3,700 with the 10% trucks. RUC was only $100 per day when subtracting RUC_P from RUC_e. Since the SR-26 Project is located in a very rural area, the low AADT of the project attributed to the extremely low RUC. Therefore, to simulate a more urban project, the research team made an assumption of high AADT (40,000) and 15% trucks. Under the simulated conditions, RUC was calculated to be about $6,800.

For CE&I costs, $36.13 and $55.71 were used for limerock and HMA base as explained in Chapter 4.

5.5 RESULT OF TOTAL COST COMPARISON

The area of limerock placed from Option Group 9 was 69,424 m² in the SR-26 Project, and for the purpose of comparison, HMA base was assumed to be used for the same area. Figure 5-3 shows the result of the total cost comparison. In order to interpret the result and develop an equation of cost comparison, the following notations were developed.

i. T_{LR} : Duration of limerock base construction
ii. T_{HMA} : Possible duration of HMA base construction if used in the area of limerock base
iii. T_E : Time when total cost of limerock equals to that of HMA
iv. DC_{LR} = Direct Cost of Limerock
v. DC_{HMA} = Direct Cost of HMA
vi. ΔDC = Direct Cost Difference

Then, the total cost can be calculated as in Equation (5-2) and (5-3).

$$\text{Total Cost of LR} = DC_{LR} + (RUC + CE\&I_{LR}) \times T_{LR} \tag{5-2}$$

$$\text{Total Cost of HMA} = DC_{HMA} + (RUC + CE\&I_{HMA}) \times T_{HMA} \tag{5-3}$$

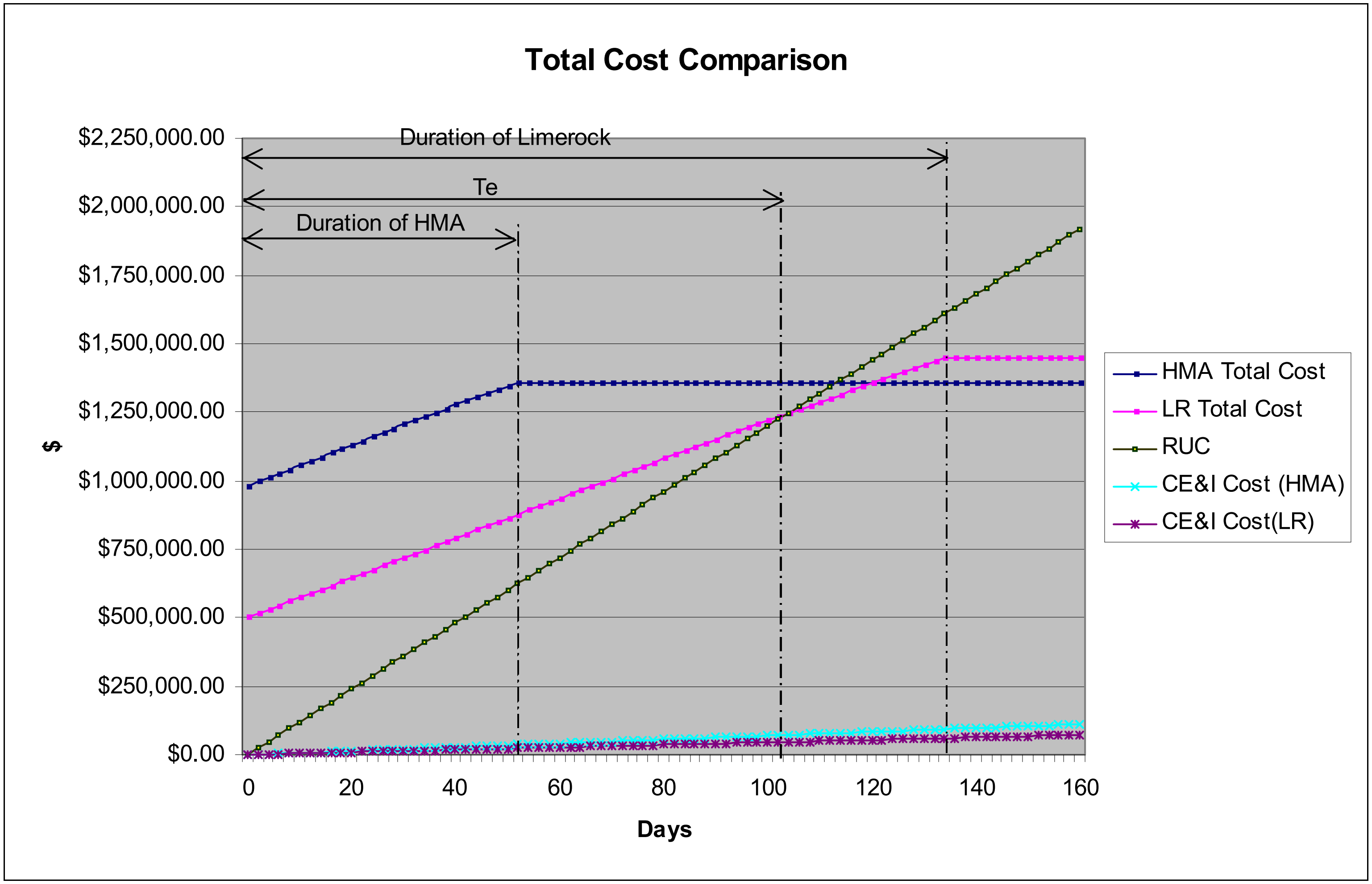

Figure 5-3. Total Cost Comparison of SR-26 Project

The direct cost difference can be calculated as in Equation (5-4).

$$\Delta DC = (T_E - T_{HMA}) \text{ x } (RUC + CE\&I_{LR}) \tag{5-4}$$

From the Equation (5-4), the value of T_E can be calculated as shown in Equation (5-5).

$$T_E = T_{HMA} + (\Delta DC / (RUC + CE\&I_{LR}) \tag{5-5}$$

Finally, the result of the total cost comparison can be measured by comparing T_E and T_{LR}. Because T_E is the time when the total costs of limerock and HMA base are equal, if the duration of limerock base is larger, the total cost of limerock base construction is more expensive than that of HMA base. It can be summarized as below.

(CASE 1) If $T_{LR} < T_E$, LR is cheaper than HMA.
(CASE 2) If $T_{LR} > T_E$, HMA is cheaper than LR.

From (CASE 2), the additional cost of limerock base can be calculated by Equation (5-6).

$$\text{Additional cost of limerock base} = (T_{LR} - T_E) \text{ x } (RUC + CE\&I_{LR}) \tag{5-6}$$

The duration of HMA base (T_{HMA}) was calculated by dividing the area of limerock base (69,424 m^2) by the production rate of HMA base (116.9 m^2/hour) and then, the total hours were divided by 8 hours per day to obtain workdays. For the SR-26 Project, the values are given below.

i. DC_{HMA} = \$979,572.64
ii. DC_{LR} = \$499,852.80
iii. ΔDC = \$479,719.84
iv. T_{HMA} = 51 days
v. T_{LR} = 135 days
vi. RUC: \$100 /day (AADT: 12,500, 10 % trucks)
vii. $CE \& I_{LR}$: \$36.13 /hr x 8 hours = \$289.04 /day
viii. $CE \& I_{HMA}$: \$ 55.71/hr x 8 hours = \$445.68 /day

By using Equation (5-5), the value of T_E was calculated as below. So limerock was the more economical choice for this project due to the extremely low RUC.

$$T_E = T_{HMA} + (\Delta DC / (RUC + CE\&I_{LR}) = 1285\ (> 135)$$

However, when the research team simulated this procedure for the same project with an assumed RUC AADT of 47,500 with 15 % trucks, the RUC rose from \$100/day to \$12,500/day. Again using Equation (5-5), the result of further analysis showed that the value of T_E was 88.5. Thus, HMA base would have been cheaper than limerock base in this scenario because the limerock construction took longer than 88.5 days. This cost comparison tool was further developed as described in Chapter 6 with an automated system generated in an Excel spread sheet.

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Florida Department of Transportation. (2004). *Standard Specifications for Road and Bridge Construction*. Retrieved Oct 12, 2003, from http://www.dot.state.fl.us/specificationsoffice/2004BK/D200.doc.pdf

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CHAPTER 6

6. DEVELOPMENT OF COST DECISION TOOL

Based on the findings from earlier chapters, the research team developed a tool that compares the total cost of limerock base and HMA base. This tool, called a Cost Decision Tool (CDT), will provide users with economic evaluations for limerock and HMA base options. Figure 6-1 shows the overall process model of the CDT. This model consists of two parts: Data Inputting and Data Processing.

6.1 DATA INPUT

The data input process requires the user to input the direct cost, CE&I costs, RUC, and proposed duration for both bases of limerock and HMA.

6.1.1 Inputting Direct Cost

Direct costs should be obtained from contract documents such as the Summary of Pay Items. FDOT applies the unit bid method for the majority of roadway projects, and a project is contracted based on the price of each bid item under the unit bid method. Each base option has the unit and quantity values furnished by FDOT and the unit price bid by the contractor.

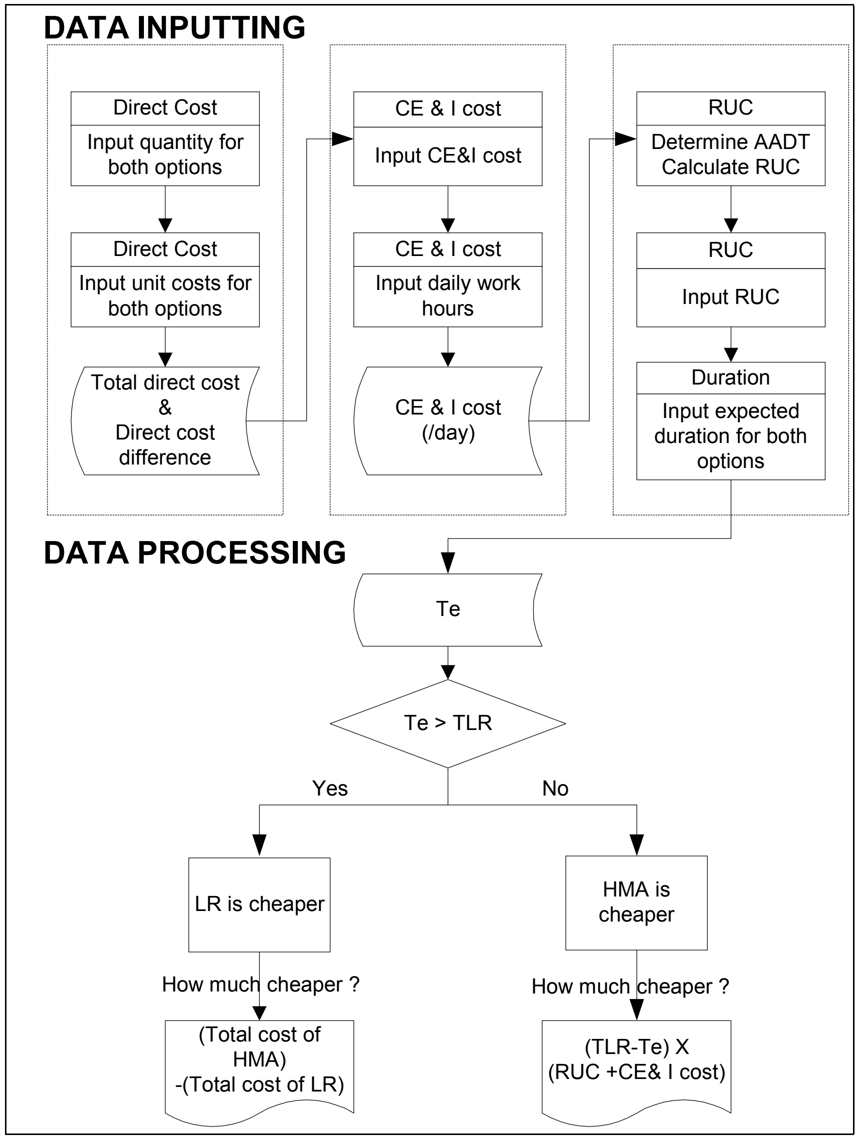

Figure 6-1. CDT Process Model

The user first inputs the quantities and unit prices for limerock base and the CDT generates the same quantities for HMA base and the unit price for HMA must then be entered. The unit prices of HMA should be obtained from historical data if such information is available. Otherwise, they can be calculated based on unit prices per SN calculated from other project data as explained in Chapter 4. The CDT then calculates the total direct cost and direct cost difference. Figure 6-2 is a snapshot of the direct cost input process in the CDT. The data from the SR-26 Project was used to demonstrate the process.

Input Limerock Option			
Optional Base	**Quantity (SM)**	**Unit Cost**	**Cost**
1-1. Option 1			$ -
1.2. Option 2			$ -
1.3. Option 3			$ -
1.4. Option 4			$ -
1.5. Option 5			$ -
1.6. Option 6			$ -
1.7. Option 7			$ -
1.8. Option 8			$ -
1.9. Option 9	69,424.00	$ 7.20	$ 499,852.80
1.10. Option 10			$ -
1-11. Option 11			$ -
1.12. Option 12			$ -
1.13. Option 13			$ -
1.14. Option 14			$ -
Total	69,424.00		$ 499,852.80

Input HMA Option			
Optional Base	**Quantity (SM)**	**Unit Cost**	**Cost**
1-1. Option 1			$ -
1.2. Option 2			$ -
1.3. Option 3			$ -
1.4. Option 4			$ -
1.5. Option 5			$ -
1.6. Option 6			$ -
1.7. Option 7			$ -
1.8. Option 8			$ -
1.9. Option 9	69,424.00	$ 14.11	$ 979,572.64
1.10. Option 10			$ -
1-11. Option 11			$ -
1.12. Option 12			$ -
1.13. Option 13			$ -
1.14. Option 14			$ -
Total	93,494.65		$ 979,572.64

Category	LR	HMA
Direct Cost ($)	$499,852.80	$979,572.64
		$479,719.84

Go to CE&I / RUC

Figure 6-2. Direct Cost Input in CDT

6.1.2 Inputting CE&I Costs and RUC

Next, CE&I cost data must be entered. The CDT allows the user to input CE&I cost data for limerock and HMA separately on a per-hour basis. The user then needs to input daily work hours by using the scroll bar, and the CDT calculates daily CE&I costs.

The RUC value is input after the user determines the AADT of the project location. RUC can be calculated by any number of manual methods such as the TTI manual method or the FDOT method or by using software such as MicroBENCOST as described in Chapters 3 and 4. Figure 6-3 shows a snapshot of the CDT at the point where the user inputs CE&I cost and RUC data.

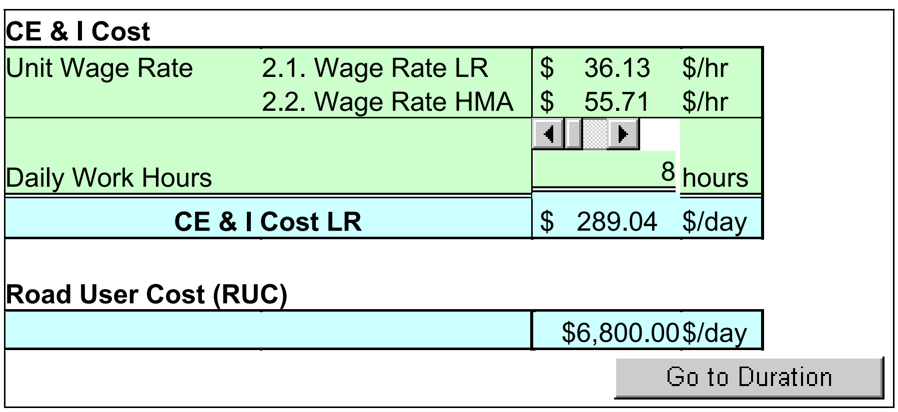

Figure 6-3. CE&I costs and RUC Input in CDT

6.1.3 Inputting Duration

The expected duration for limerock base construction is then input, followed by the duration of the work if HMA were chosen. If historical records are not available, the production rate as calculated in Chapter 4 may be used to calculate the duration since the statistical test showed that the production rates of three ongoing projects were not different at the α = 5% level. Figure 6-4 shows a snapshot of the process of inputting duration.

Duration		LR	HMA
	Expected Days	135	51
	Te*	85.5	

Te: Time when total cost of LR is equal to that of HMA.

See the result

Figure 6-4. Duration Input in CDT

6.2 DATA PROCESSING

Once the expected durations of limerock and HMA are input, the CDT calculates the value of T_E. Again, T_E is the time (duration) when the total cost of limerock equals to that of HMA. After comparing the value of T_E to the duration of limerock work (T_{LR}), the CDT returns the result of its economic evaluation.

The CDT provides the answer of which base material will be the most economical for a particular project. If T_{LR} is shorter than T_E, limerock is a less expensive option than HMA. The CDT calculates the cost difference by subtracting the total cost of limerock from the total cost of HMA base. If T_{LR} is longer than T_E, HMA is a less expensive option than LR. The CDT calculates the extra cost of limerock base as shown in Equation (5-6) in Chapter 5. Figure 6-5 shows a snapshot of the result in the CDT.

$$\text{Additional cost of limerock base} = (T_{LR} - T_E) \times (RUC + CE\&I_{LR}) \qquad (5\text{-}6)$$

Result	HMA is cheaper
How much cheaper?	$ (6,263.68)

Figure 6-5. The Result of CDT

In Chapter 6, the structure and process of the CDT has been described. By using the CDT, the research team performed cost evaluations for other projects. This process is presented in Chapter 7.

Reference:

Daniels, G., Ellis, D. R., & Stockton, W. R. (1999). *Techniques for Manually Estimating Road User Costs Associated with Construction Projects*. Texas Transportation Institute

CHAPTER SEVEN

7. CASE STUDIES AND RESULT ANALYSIS

The research team applied the CDT to all the limerock base projects investigated as part of this study. The procedure of CDT was presented in Chapter 6. It is important to note that:

1. Prices and quantities for the mainline area where limerock base was constructed were replaced with prices and quantities for HMA base to compare the total costs. In order to calculate the unit price of HMA for the various base options, unit prices per SN ($7.75 /SN) obtained from the SR-26 Project were used by multiplying the price by the SN required for the respective limerock options in use.
2. The CE&I costs from the SR-26 Project were used because all the projects were performed within two years of this project. Changes in CE&I costs over a two-year time period are minimal.
3. The tables presented in the TTI manual (1999) were used to calculate RUC. Again, RUC depends on AADT and percent trucks. Ten percent trucks for the rural projects and 15 % trucks for the urban projects were applied.
4. The duration of limerock base construction was obtained from the project data, and the area of limerock base was divided by the production rate of HMA (116.9 m^2/hr) to calculate the total work hours required if the HMA base had been used. Then, the work hours were converted to workdays to calculate the number of workdays of base construction would have been necessary if HMA had been used.

7.1 SR-20 (Alachua County)

Table 7-1 shows the cost and production data of the SR-20 Project.

Table 7-1. Cost and Production Data of SR-20 (Alachua)

Item description	Item Number	Plan Qty	Unit	Unit price
Base option1	2285701	21,167.00	m^2	$7.95
Base option 6	2285706	76,593.00	m^2	$7.00

Total SM completed by	7/28/2003	19,422.00
Total WH for work finished by	7/28/2003	467
Total Lane (Mile)	3.35	
Total work day	50	
m^2 /WH	41.59	
WH/LM	139.40	

19,422.00 m^2 of Base Option Group 6 limerock was completed as of July 28, 2003. The area quantity was input in the CDT to determine the direct cost difference when HMA base was used. The unit price of HMA for Base Option 6 was calculated by multiplying 1.44 (SN for Option 6) by $7.75 /SN (unit price per SN), which was obtained from the SR-26 Project.

Because the project is located in a rural area with an AADT of 11,500 and 10% trucks, RUC were only $100 per day (FDOT, 2002c). T_{LR} was 50 days, and T_{HMA} was calculated when dividing the area by 116.9 m^2/hr and dividing the value again by 8 hrs/day. This calculation returns a 21-day duration. These data were input to the CDT and Figure 7-1 shows the result in a screen shot of the CDT.

Input Limerock Option			
Optional Base	Quantity (SM)	Unit Cost	Cost
1-1. Option 1			$ -
1.2. Option 2			$ -
1.3. Option 3			$ -
1.4. Option 4			$ -
1.5. Option 5			$ -
1.6. Option 6	76,593.00	$ 7.00	$ 536,151.00
1.7. Option 7			$ -
1.8. Option 8			$ -
1.9. Option 9			
1.10. Option 10			$ -
1-11. Option 11			$ -
1.12. Option 12			$ -
1.13. Option 13			$ -
1.14. Option 14			$ -
Total	76,593.00		$ 536,151.00

Input HMA Option			
Optional Base	Quantity (SM)	Unit Cost	Cost
1-1. Option 1			$ -
1.2. Option 2			$ -
1.3. Option 3			$ -
1.4. Option 4			$ -
1.5. Option 5			$ -
1.6. Option 6	76,593.00	$ 11.16	$ 854,777.88
1.7. Option 7			$ -
1.8. Option 8			$ -
1.9. Option 9			$ -
1.10. Option 10			$ -
1-11. Option 11			$ -
1.12. Option 12			$ -
1.13. Option 13			$ -
1.14. Option 14			$ -
Total	93,494.65		$ 854,777.88

Category	LR	HMA
Direct Cost ($)	$536,151.00	$854,777.88
Difference of DC		$318,626.88

Go to CE&I / RUC

Figure 7-1. The CDT Simulation for SR-20

CE & I Cost			
Unit Wage Rate	2.1. Wage Rate LR	$ 36.13	$/hr
	2.2. Wage Rate HMA	$ 55.71	$/hr
Daily Work Hours		8	hours
CE & I Cost LR		$ 289.04	$/day
Road User Cost (RUC)			
RUC		$100.00	$/day

Go to Duration

Duration		LR	HMA
	Expected Days	50	20.8
	Te*	839.8	

Te: Time when total cost of LR is equal to that of HMA.

See the result

Result	LR is cheaper
How much cheaper?	$ 307,254.37

Figure 7-1. The CDT Simulation for SR-20 (continued)

As shown by the CDT result, the limerock base option was more economical for this project. Even though the production rate of HMA base construction over limerock base was 281%, the very low RUC led to this result.

7.2 SR-500 (Alachua)

Table 7-2 shows the cost and production data for the SR-500 Project.

Table 7-2. Cost and Production Data of SR-500 (Alachua)

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 1	2285701	45,555.00	m^2	\$5.15
Base option 9	2285709	121,946.42	m^2	\$7.00

Total SM completed by	9/16/2002	121,946.42
Total WH for work finished by	9/16/2002	1843.00
Total Lane (Mile)	21.326	
Total work day	203	
m^2/WH	66.17	
WH/LM	86.42	

121,946.42 m^2 of Base Option Group 9 limerock was completed on September 16, 2002. The area quantity was input in the CDT to determine the direct cost difference when HMA base was used. The unit price of HMA for Base Option 9 was calculated by multiplying 1.8 (SN for Option 9) by \$7.75 /SN (unit price per SN).

Because the project is located in a rural area with an AADT of 13,000 and 10% trucks, RUC were only \$200 per day (FDOT, 2002c). T_{LR} was 203 days, and T_{HMA} was found to have a 134-day duration. These data were input to the CDT and Figure 7-2 shows the result in a screen shot of the CDT.

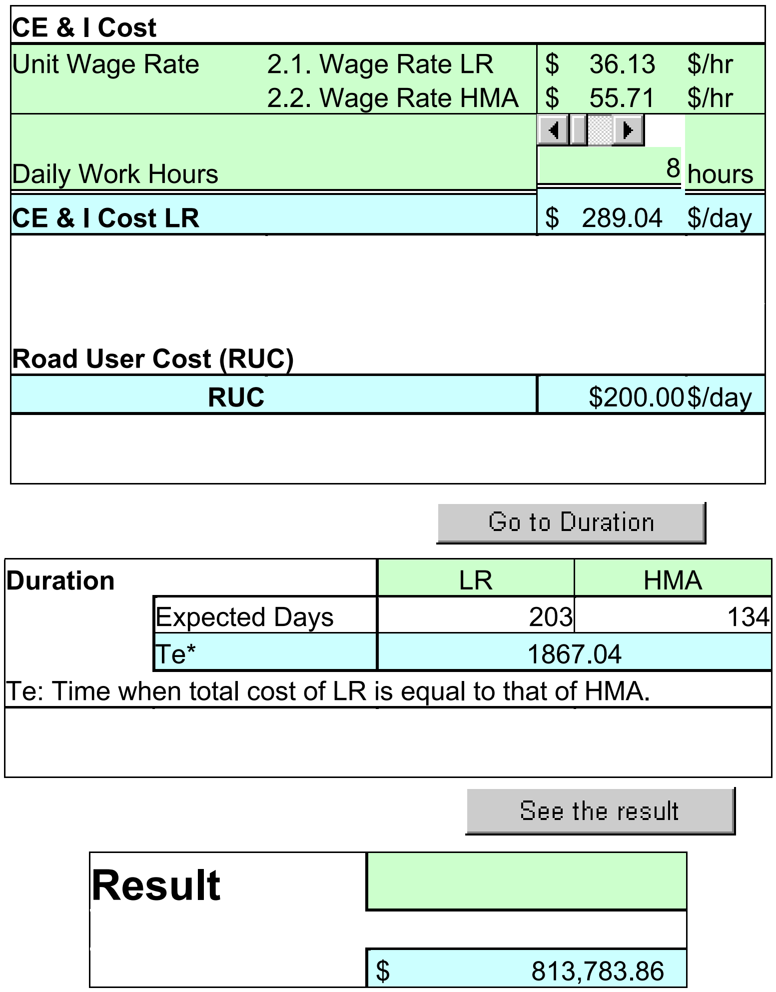

Figure 7-2. The CDT Simulation for SR-500

As shown by the CDT result, limerock base option was more economical for this project. Even though the production rate of HMA base construction over limerock base was 177%, the very low RUC led to this result.

7.3 Capital Circle (Tallahassee)

Table 7-3 shows the cost and production data of the Capital Circle Project.

Table 7-3. Cost and Production Data of Capital Circle (Tallahassee)

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 9	2285709	15,600.00	m^2	\$6.65
Base option 16	2285716	20,043.66	m^2	\$8.58

Total m^2 completed by	6/17/1999	35,643.66
Total WH for work finished by	6/17/1999	396.5
Total Lane (Mile)	6.68	
Total work day	42	
m^2/WH	89.90	
WH/LM	59.31	

35,643.66 m^2 of limerock from Base Option Groups 9 and 16 was completed on June 17, 1999. The area quantity was input to the CDT to determine the direct cost difference when HMA base was used. The unit prices of HMA for Base Option Groups 9 and 16 were calculated by multiplying 1.8 (SN for Option 9) and 2.72 (SN for Option 16) by \$7.75 /SN (unit price per SN).

Because the project is located in an urban area with an AADT of 87,500 and 15% trucks, RUC was much higher (\$44,000 per day). (FDOT, 2002c) T_{LR} was 42 days, and T_{HMA} was calculated by dividing the area by 116.9 m^2/hr and dividing the value again by 8 hrs/day, yielding duration of 39 days.

Even though the project was located in an urban area, resulting in much higher RUC, limerock base construction was still the more economical option for this project. If the limerock construction had taken more than 47 days, HMA base would have been more economical.

7.4 I-95 (Duval County)

Table 7-4 shows the cost and production data of the I-95 Project.

Table 7-4. Cost and Production Data of I-95 (Duval)

Item description	Item Number	Plan Qty	Unit	Unit price
Base option (Base group M8)	2285708	139,606.00	m^2	\$7.97
Base option (Base group M12)	2285712	166,385.00	m^2	\$10.74

Total SM completed by	5/31/2002	255,847.45
Total WH for work finished by	5/31/2002	3015.00
Total Lane (Mile)	46.930	
Total work day	377	
m^2/WH	84.86	
WH/LM	64.24	

255,847.45 m^2 of limerock from Base Option Groups 8 and 12 were completed as of May 31, 2003. The area quantity was input to the CDT to determine the direct cost difference when HMA base was used. The unit prices of HMA for Base Options 8 and 12 were calculated by multiplying 1.68 (SN for Option 8) and 2.28 (SN for Option 12) respectively by \$7.75.

Because the project was located in an urban area with a high AADT (62,500) and 15% trucks, the RUC was high (\$24,000 per day). (FDOT, 2002c) T_{LR} was 377 days, and T_{HMA} was found to be 264-days. These data were input to the CDT and Figure 7-3 shows the results in a screen shot of the CDT.

CE & I Cost			
Unit Wage Rate	2.1. Wage Rate LR	$ 36.13	$/hr
	2.2. Wage Rate HMA	$ 55.71	$/hr
Daily Work Hours		8	hours
CE & I Cost LR		$ 289.04	$/day

Road User Cost (RUC)		
RUC	$24,000.00	$/day

Go to Duration

Duration		LR	HMA
	Expected Days	351	264
	Te*	329.75	

Te: Time when total cost of LR is equal to that of HMA.

See the result

Result	HMA is cheaper
How much cheaper?	$ (516,116.94)

Figure 7-3. The CDT Simulation for I-95

As shown by the CDT result, the HMA base option was more economical for this project.

7.5 SUMMARY

Table 7-5 summarizes all projects investigated. From the result of the case studies, the research team showed that the projects in rural areas with their inherent low RUC, tended toward the limerock option. However, in urban areas with high RUC, the usage of HMA can be justified by the total cost comparison.

Table 7-5. Summary of Case Studies

Projects	**SR-20**	**SR-500**	**Capital Circle**	**I-95**
Location	Rural	Rural	Urban	Urban
% Trucks	10%	10%	15%	15%
AADT	11,500	13,000	87,500	62,500
RUC	$100	$200	$44,000	$24,000
CE & I $_{LR}$	$289.04	$289.04	$289.04	$289.04
DC $_{HMA}$	$854,777.88	$1,701,152.56	$640,140.35	$4,104,824.05
DC $_{LR}$	$536,151.00	$853,624.94	$275,714.60	$2,499,990.63
ΔDC	$318,626.88	$847,527.62	$364,425.75	$1,604,833.42
Production rate (m^2/hour)	41.59	66.17	89.90	84.86
T $_{HMA}$	21	134	39	264
T $_{LR}$	50	203	42	351
T $_{E}$	839.8	1,867	48	330

It is possible to reverse the analysis procedure of course. Instead of replacing the limerock area with HMA from the limerock base projects, the HMA area could be replaced with limerock from the HMA base projects and if this analysis was performed, it is expected that the results would be consistent with those found during this investigation.

References:

Daniels, G., Ellis, D. R., & Stockton, W. R. (1999). *Techniques for Manually Estimating Road User Costs Associated with Construction Projects*. Texas Transportation Institute

Florida Department of Transportation. (2002c). *Annual Average Daily Traffic Reports*. Retrieved Jun 15, 2003, from http://http://www11.myflorida.com/planning/statistics/trafficdata/AADT

CHAPTER EIGHT

8. CONCLUSION

The effort made by the research team to perform an economic evaluation between the limerock and HMA base options includes:

- The research team conducted an extensive data collection process with the help of construction project personnel, gathering data from various sources including interviews, project visits, and project documents.
- The direct cost difference between two base options was calculated by applying the unit price per SN. This method was valid to determine the direct cost difference between two options within the same optional base group, especially when historical data are not available.
- The research team determined the production rate of HMA base construction for three active projects. The projects included both urban and rural projects. The statistical analysis showed that the production rates were consistent if the number of lifts is the same.
- RUC were a determining factor in total cost comparison. The method of calculation of RUC can and should be customized to project type (rehabilitation or adding capacity). If a lane closure is required, higher RUC are expected as presented in Chapter 3.
- From the SR-26 Project, the research team measured the production rate of both options. Because of the homogeneity of the data (same contractor, time, and location), this project was used for the pilot study as presented in Chapter 5.

- From the pilot study of the SR-26 Project, the research team developed the CDT that effectively performs a cost comparison as presented in Chapter 6.
- The CDT was used to evaluate other projects investigated as presented in Chapter 7. From the evaluation, it was found that project location was a significant factor because the high AADT causes high RUC, which is a decisive factor in the total cost comparison.

Even though the direct costs of limerock base were lower than those for HMA base, limerock base is not always more economical when considering total cost. High RUC and CE&I costs may justify the use of HMA base. Typically, this means the higher the AADT and the longer the expected duration of base construction, the more likely it is that HMA is the most economical choice in base material.

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APPENDICES

APPENDIX A

PLEXIBLE PAVEMENT DESIGN MANUAL

TABLE 5.6
GENERAL USE OPTIONAL BASE GROUPS AND STRUCTURAL NUMBERS
(STANDARD INDEX 514) (mm)

BASE THICKNESS AND OPTION CODES										
			Base Options							
Base Group	Structural Range	Base Group Pay Item Number	Limerock LBR 100	Cemented Coquina LBR 100	Shell Rock LBR 100	Bank Run Shell LBR 100	Graded Aggregate Base LBR 100	Type B-12.5	B-12.5 And 100mm Granular, Subbase LBR 100˙	RAP Base
			Structural Number (Per.mm)							
			(.18)	(.18)	(.18)	(.18)	(.15)	(.30)	(.30&.15)	(NA)
1	16-20	701	100	100	100	100	100	100 ^		130□
2	20-23	702	120	120	120	120	140	100 ^		
3	24-27	703	140	140	140	140	160	100 ^		
4	27-29	704	160	160	160	160	190	100 ^		
5	31-34	705	180	180	180	180	210	110		
6	34-39	706	200	200	200	200	230	120		
7	39-42	707	220	220	220	220	260	130		
8	42-44	708	240	240	240	240	280	140		
9	44-47	709	260	260	260	260	300	150	100	
10	48-51	710	280	280	280	280	330 ^	160	110	
11	52-55	711	300	300	300	300	350 ^	180	130	
12	55-58	712	320	320	320	320		190	140	
13	59-62	713	340 ^	340 ^	340 ^	340 ^		200	150	
14	62-65	714	360^	360 ^	360 ^	360 ^		210	160	
15	66-69	715						220	170	

˙ For granular subbase, the construction of both the subbase and Type B-12.5 will be paid for under the contract unit price for Optional Base. Granular Subbases include Limerock, Cemented Coquina, Shell Rock, Bank Run Shell and Graded Aggregate Base at LBR 100. The base thickness shown is Type B-12.5. All subbase thickness are 100mm(4").

⊖ To be used for Widening only, one meter or less.
^ Based on minimum practical thickness.
□ Restricted to non-limited access shoulder base construction.

Page 5.15.0

5.5.2 Base

For the purpose of base determination, FDOT allows the contractors to choose the least expensive material as described below (Adopted from Flexible Pavement Design Manual): Except as limited by Standard Index 514 or as may be justified by special project conditions, the options for base material should not be restricted. Allowing the contractor the full range of base materials will permit him to select the least costly material, thus resulting in the lowest bid price.

Unbound granular base materials are generally the least expensive. Project conditions may dictate restricting the base course to Asphalt Base Course. The following conditions may warrant restricting the base course to Asphalt Base Course (Type B-12.5) if the additional cost can be justified:

< In an urban area, maintenance of access to adjacent business is critical to the extent that it is desirable to accelerate base construction.

< The maintenance of traffic scheme requires acceleration of base construction in certain areas of the project.

< High ground water and back of sidewalk grade restrictions make it difficult to obtain adequate design high water clearance from the bottom of a thicker limerock base. The thinner asphalt base can help increase the clearance. NOTE that asphalt base requires a well-compacted subgrade, as does limerock base. It is usually necessary to have two feet(0.6 m) clearance above ground water to get adequate compaction in the top foot(0.3 m) of subgrade. In areas where this cannot be obtained, the District Drainage Engineer should be consulted for an underdrain design or other methods to lower the ground water.

< The configuration of base widening and subgrade soil conditions are such that accumulation of rainfall in excavated areas will significantly delay construction. The Pavement Design Engineer should become familiar with the material properties, construction techniques, testing procedures, and maintenance of traffic techniques that may enter into the decision to restrict the type of base material to be used. Consultation with the District Construction Engineer and the District Materials Engineer should be done prior to making any decision

A decision to restrict base course material to an Asphalt Base Course throughout a project must be documented and approved by the District Design Engineer. A copy of the documentation shall be furnished to the State Pavement Design Engineer.

Base courses are normally set up under Optional Base Group (OBG) bid item. On projects where the Pavement Design Engineer would like to use Asphalt Base (Type B-12.5) on a part of a project and allow multiple base options on other parts of the project, the Pavement Design Engineer should change the Optional Base Group (OBG) Number by one and specify Asphalt Base only for the area where it is required.

An example of a project where this may occur would be on a project where OBG 6 is recommended and the Pavement Design Engineer encounters an area of high water. The option would be to use Type B-12.5 from OBG 7. Another option would be to use Type B-12.5 from OBG 5. In both cases the structural asphalt thickness can be adjusted to meet the structural number requirements and allow for separate unit prices.

The Optional Base Group should not exceed Optional Base Group 12 for unbound granular base materials, except for trench widening where up to Optional Base Group 14 may be used.

APPENDIX B

AN EXAMPLE OF COST COMPARISON

ABC VS. LIMEROCK COST COMPARISON

[provided by John C. Hipp Construction]

ulations based on:	one mile (one edge) of two foot widening strip base & structure range 10, index 514		
CTIVITIES	10 ½ inches LIMEROCK	6 ½ inches ABC-3	A
grass lar excavation	box + grader -- 2 passes broom -- 2 passes labor, loader 508cy at $5.00/cy = $2,540.00	box + grader -- 1 pass broom -- 1 pass labor, loader 297 cy at $5.82/cy = $1,728.54	strip regu
& excavation ft ift & prime	truck & trailer, cones, 3 laborers, 2 flaggers with radios 1 pass per 10 hour day 4 passes at $562.50/day = $2,250.00	truck & trailer, cones, 3 laborers, 2 flaggers with radios 1 pass per 10 hour day 3 passes at $562.50/day = $1,687.50	MO 1st li 2nd finis
ials delivered te	634 tons of limerock used (with 30% waste) 824 tons at $7.18/ton + prime & sand at $513.00 = $6,429.32	382 tons of ABC-3 used (with 15% waste) 439 tons at $25.32/ton = $11,115.48	mate on si
llation our day)	grader with box spreader, grader, 2 loaders, roller, water truck, broom $4,950.00	grader with box spreader, loader, roller, water truck, broom $3,350.00	instal (10 h
ing	2 graders, 2 rollers, loader, broom, labor, water truck $3,080.00	N/A $0.00	finish
ND TOTAL	$19,249.32/mile	$17,881.52/mile	GRA
8 - 881 - 7875	Limerock prices are stable and since stockpiling is possible, contractor can install at his convenience. Material costs are low, but equipment and labor costs are high.	Using asphalt is a greater risk due to weather restrictions and must be installed at plant's convenience. Material costs are high, but less effort required (also much faster).	

ransmittal memo 7671 # of pages >

From K.E. Bryan

Co.

Phone # 386-312-4820

Fax #

R. N. ELKE 1 3:00

19 386-758-3700

8-881-3700

Post-it™ brand fax

Ananth

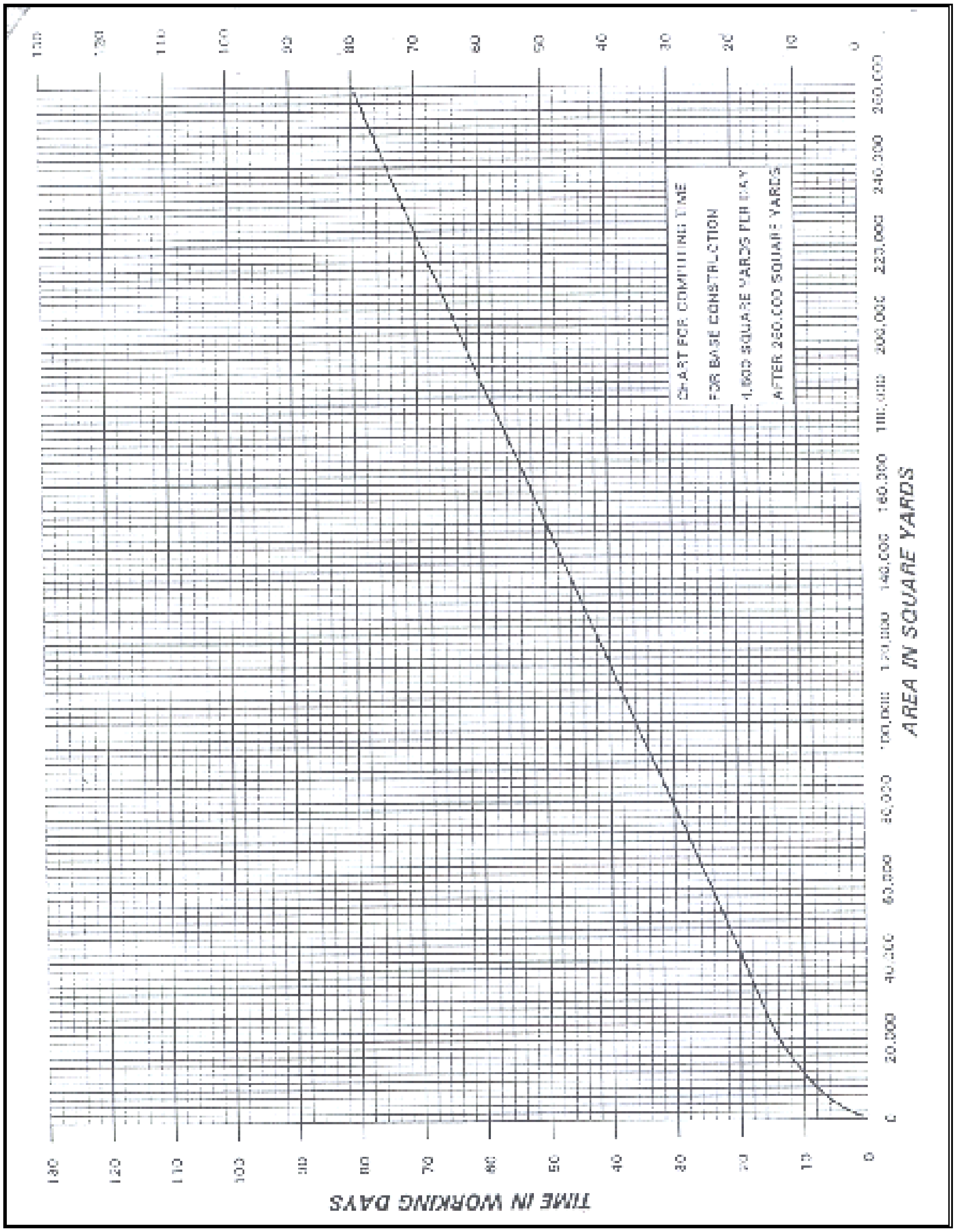
Co.

Dept.

Fax #

APPENDIX C

<u>WORKING DURATION FOR LIMEROCK BASE CONSTRUCTION</u>



APPENDIX D

PRODUCTION MEASUREMENT FORM

SR 20 - HAWTHORNE BASE CONSTRUCTION			
Today's Date:		LIFT CONSTRUCTED:	Mainline 1 Lift; Left/Right Shoulders
QUANTITIES			
Mainline Thickness (mm):		Quantity Dumped (MT):	
Shoulder Thickness (mm):		Quantity Spread (MT):	
Mainline Width (M):		Mainline Compacted (M2):	0
Left Shoulder Width (M):		Shoulders Compacted M2:	0
Right Shoulder Width (M):			
Sta From:	Sta To:	Total Length (M):	0

WORK CREW		
	No.	Hours
Foreman:		
Skilled:		
Semi-Skilled:		
Laborer:		

EQUIPMENT		
Type	No.	Hours

INCIDENTS THAT AFFECT PRODUCTION

		LIFT CONSTRUCTED:	
QUANTITIES			
Mainline Thickness (mm):		Quantity Dumped (MT):	
Shoulder Thickness (mm):		Quantity Spread (MT):	
Mainline Width (M):		Mainline Compacted (M2):	0
Left Shoulder Width (M):		Shoulders Compacted M2:	0
Right Shoulder Width (M):			
Sta From:	Sta To:	Total Length (M):	0

WORK CREW		
	No.	Hours
Foreman:		
Skilled:		
Semi-Skilled:		
Laborer:		

EQUIPMENT		
Type	No.	Hours

INCIDENTS THAT AFFECT PRODUCTION

APPENDIX E

MEMORANDUM FOR THE USAGE OF HMA BASE

Current policy in D2

MEMORANDUM

FLORIDA DEPARTMENT OF TRANSPORTATION
DISTRICT II CONSULTANT PROJECT MANAGEMENT

DATE: August 31, 2001

SUBJECT: Minutes of Joint Meeting with Production and Operations

1. Delivery & Ownership of RAP Material – The increased use of superpave asphalt and the frequency of existing paved shoulders has increased the opportunity to have excess RAP material on certain jobs. Maintenance units will be allowed to request ownership of a specific number of lane miles of RAP material from selected jobs. Try to keep at least a ratio of 50% for the contractor. This request shall be made at the scoping stage of the project. Requests later in plans development will be denied. The receiving yard should be in close proximity (10 miles) to the milling work area and it should be large enough to handle the volume of material that will be delivered. Stacking and shaping of the stockpile will be the responsibility of the receiving unit and will not be included as part of the delivery by the Contractor. The Department will not take possession of RAP material on county road projects. No RAP material will be given to Counties or local governments.
2. Stabilizing Private Driveways with RAP Material – Selective use will be permitted provided the roadway already has paved shoulders. This request shall be made at the scoping stage of the project. Requests later in plans development will be denied. The maintenance unit will have to decide to choose delivery of RAP to the maintenance yard or placement of RAP on driveways. Both items of work will NOT be preformed on a single project.
3. Desilting of Drainage Pipes – Wholesale desilting of existing storm sewer systems and cross drains will not be done. Specific locations may be considered during the scoping process. This is a non participating item of the FHWA and designer discretion should be used especially in the case of cross drain extensions.
4. Cleaning of Lateral Ditches – Ditches will only be cleaned if a drainage problem exists. This item remains unchanged from 1996.
5. Regrading of Roadside Ditches – Roadside ditches will only be graded if a drainage problem exists. This item remains unchanged from 1996. However, designers should be using an MES detail that shows grading 25' from the end of new MES on RRR projects.
6. Double 42" Sod Strip – We will continue to use a single 42" sod strip.

7. Sign Mounting Heights – Item remains unchanged from 1996 at 7' mounting height. Design will continue to include this note – Standard Index 17302 Note 5 is modified to read: All signs shall have a minimum mounting height of 7 feet as measured from the bottom of the sign panel to a horizontal line extended from the edge of the driving lane or sidewalk, whichever is higher. This includes rural sections and secondary sign panels. Construction will emphasize sign mounting height early on during the construction contract.
8. Extending Base Under the Curb – Urban reconstruction projects will be black base with base extended under the curb pad and no stabilization. The extra base will be included in the cost of the curb. Existing projects will not be revisited.
9. Request to Use FC-5 on Two Lane Facility – District Office Construction has coordinated this request through central office pavement design. Bruce Dietrich, State Pavement Design Engineer, has denied this request.
10. FC-5 Within Median Crossovers – The Pavement Design Manual will be revised to allow Districts the option to pave median crossovers at the recommendation of the Construction Office. Henry Haggerty will send a memo to Robert Pearce requesting his concurrence to pave median crossovers.
11. Right of Way Requirements – Consider the increased need for tree mitigation (landscaping) when setting right of way requirements for retention ponds and roadway. Also, provide access to ponds for maintenance activities.
12. As-Built Survey of Ponds – Begin providing as-built drawings for ponds on all projects. It will be the Contractor's responsibility to provide these as-builts. The Specification Office will pursue a special provision for District 2.
13. Sidewalk Repair – Broken Sidewalk that poses a safety hazard will be replaced during resurfacing projects. Exceptions to this will be established during the work program building cycle.
14. Projects with Existing Paved Shoulders – The approach will be to stay off the grassed shoulder unless there is a specific reason for shoulder work. This determination needs to be made during the scoping stage. Guidelines for when to do shoulder work will be if the buildup exceeds 2" or the drop-off exceeds 3".
15. Constructability, Time & Money – The Florida Statutes, Title XXVI, Chapter 337, Section 337.015 recognizes time as an essential element of the contract. Time and money should be considered when evaluating engineering options.
16. Black Base Pavement Design – The following project types shall be a black base pavement design: urban reconstruction, intersection improvement, turn lane additions, and widening less than 5' in width.

ACTION ITEMS

- Construction will investigate different methods of sealing pipe joints.
- Production will include Operations in the future plan of eliminating formal phase reviews during plans development.

FLORIDA
LAWTON CHILES
GOVERNOR

DEPARTMENT OF TRANSPORTATION

District Two
1901 South Marion Street - Lake City, Florida 32056-1089
(904) 758-3742

BEN G. WATTS
SECRETARY

old policy
superseded by
8-31-01 memo

MEMORANDUM

DATE: December 11, 1996

TO: Project Scoping Meeting Attendees, Ken Morefield, Jim MacLaughlin, Aage Schroder

FROM: Lucy R. Hawkins, Director of Production

COPIES: File

SUBJECT: Work Program Scoping Meeting - November 8, 1996

The following issues were brought up at the previous scoping meeting that required a district position.

CLEANING OF LATERAL DITCHES AS A PART OF RESURFACING: Ditches will only be cleaned if a drainage problem exists. Cleaning of ditches for the purpose of improving maintenance conditions is not to be a part of resurfacing projects. If a drainage problem is identified by the area maintenance engineer, they should notify the design project manager who will ask the District Drainage Engineer for a recommendation. The Drainage Engineer's recommendation will be followed.

The district is allocated $135,000 per lane mile to resurface our roadways; this allocation includes upgrading safety deficiencies. This is the average statewide cost and is used by Central Office to distribute funds to the districts. We are required to resurface a specific number of lane miles each year. If the cost of resurfacing exceeds the amount of dollars allocated for this purposes, then the additional dollars must come from our allocation of funds to do all the other things we must do such as build new highways. Outfall ditches normally contain wetland conditions that require mitigation and these costs are not included in our allocation of money for resurfacing.

FORTY-TWO INCH SOD ALONG THE EDGE OF PAVED SHOULDERS: All unpaved shoulders are to receive a 42 inch sod strip. This is to be called for on all future construction projects. 42" = 1.1 m 16" = 0.4 m per R.D. Pearce 5-15-98

SIGN MOUNTING HEIGHTS: Maintenance requested that all signs be mounted at 7 feet high, overriding the Department's standard which allows for signs to be mounted between 5 and 7 feet.

All future plans are to call for a mounting height of 7 feet. This will be consistent with direction that has been given to our maintenance crews that are replacing signs.

RECONSTRUCTION OR RESURFACING PAVED DRIVEWAYS: All asphalt paved driveways disturbed during construction, such as trenching for utilities or storm sewer, are to be resurfaced to the right of way line. Trenches across concrete driveways should be patched to match the existing driveway.

RETENTION POND DESIGNS: It is recognized that many of our existing retention ponds are not working as they were originally intended to work. Most, if not all the problems, have been well documented. The District Drainage Engineer is responsible for proper retention pond designs. Each pond is designed based on the site specific conditions. Recent changes to statewide standards, as well as a change in district philosophy, should result in better designed ponds. Whenever possible, we should work towards joint use retention ponds with the property owner accepting responsibility for maintenance. If this is not possible, then special attention is to be given to future maintenance needs. Maintenance is to review all retention pond designs before right of way acquisition begins. Fencing of ponds has also been another issue widely discussed. We will be following the Department standards or local government standards, whichever is the most restrictive.

SIDE DRAIN PIPE REPLACEMENT: Engineering judgement should be used on a project by project basis. The designer and construction engineer are responsible for deciding if an acceptable culvert installation can be achieved by leaving the existing pipe in place and extending with mitered end sections. This is the construction engineer's call and is to be determined at the phase I plans review. If 50% or more of the pipes need to be replaced on a project, then we should replace all side drains. Again, these costs are to be covered out of the $135,000 per lane mile allocated for resurfacing. Hopefully, this issue will resolve itself as we go back to resurface roadways where mitered end sections have already been installed.

THICKNESS OF CONCRETE APRONS AROUND END WALLS: Maintenance has requested that the concrete around end walls be increased over the thickness called for in the standards. This is because they have experienced the concrete breaking due to the weight of mowing equipment. Since this is a statewide standard, we will work toward having the standards revised. Robert Pearce has been given the assignment of addressing this through the Design Office and Bobby Johns through the Maintenance Office.

REGRADING OF ROADSIDE DITCHES: This is seen as a problem since most of the time existing side drains and ditches have silted up through the years and when the side drain is replaced or extended, only approximately 15 or 20 feet is graded out at the end of the side drain. Maintenance has requested that the ditches be cleaned to prevent ponding of water at the ends.

Unless the ditch has silted to the point that it is causing flooding of the roadway or adjacent property, roadside ditches will not be cleaned on resurfacing projects.

USE OF ASPHALT BASES: The Department standard is optional bases. Exceptions to this standard are allowed on a case by case basis. Certainly, areas to consider for restricting the base course to asphalt is in urban areas on intersection improvement projects and reconstruction projects where, due to high traffic volumes, it would be beneficial to the public to expedite the construction of the base material. Engineering reasons, such as wet subgrade conditions, would justify use of an asphalt base. In any case, a justification is required. If construction feels that it is the best construction technique, then a memo is to be sent to the District Design Engineer for concurrence. This justification is to be placed in the pavement design files.

FRICTION COURSE USES: Again, the Department standards allow optional friction courses in certain conditions. The statewide standard will be used unless a justification is forwarded to the District Design Engineer for concurrence.

UTILITY LOCATION: The District recently adopted a new position on locating utilities during the plans development phase. Future surveys will be conducted to locate all utilities before the design process begins.

LIMEROCK BASE EXTENDING BEYOND THE PAVED SHOULDER EDGE: Maintenance requested that the limerock base under paved shoulders be cut off at the pavement edge, not extend 3 inches beyond pavement edge. Plans produced in the District over the past year have shown on the typical section the base being cut off at the edge of pavement. Construction personnel point out that this conflicts with Standard Index 506, in that the limits of payment is shown to 3 inches beyond the pavement edge, contractors argue that they are entitled to payment to 3 inches beyond pavement edge. Standard Specifications 5-2 states that in cases of discrepancy, the plans govern over Road Design Standards. The intent of the detail on Standard Index 506 is to show removal of excess base. Robert Pearce is working with the Central Office to have the limits of payment removed from this detail. Until the standards are changed, our position should be that the plans override the Standard Index. extend base 3" = 0.1m per Huey Hawkins 1-6-97

STABILIZING PRIVATE DRIVEWAYS WITH RAP MATERIAL: Maintenance requested that private dirt driveways be stabilized with available RAP material during construction. Further discussion was held concerning the possibility of providing Maintenance with RAP material from construction projects and they could stabilize driveways on an as needed basis. This approach was agreeable with the Maintenance Engineers.

Generally there is very little, if any, available RAP material left from two lane rural resurfacing projects due to the allowable reuses by the road contractor. Interstate resurfacing projects may be the best source of excess RAP material not needed for resurfacing the existing road. Therefore, on future interstate resurfacing projects, the design project manager is to contact the area maintenance engineer and advise them that RAP material will be available from the project. The Maintenance Engineer is to designate the site for stockpiling and will make equipment and personnel available to keep the stockpile shaped up for the contractor.

These were the major broad issues that we made note of during our two meetings. If anyone feels that we have not covered all of the districtwide issues, please send me a note and I will provide a response to everyone as soon as possible.

Individual project scopes are being written by the assigned design project manager. Copies of their notes and scopes will be made available during the plans review phases for future reference.

I would like to thank everyone who has participated in the two scoping meetings that have been held in the District. Although we have not resolved all of the issues that bug each of us from time to time, I think we are making progress toward resolution through our open discussions.

Future meetings will be held in the spring and fall of each year. During the spring meeting we will be discussing individual projects that the design folks will begin design on the following fiscal year. The fall meeting will address new projects being added to the work program. After a period of time each project will be reviewed two times, one at the time it is entered into the work program and the second time just before final plans preparation begins.

Again thank you and let me know your thoughts on improving our processes.

HH:tp

APPENDIX F

MONTHLY / WEEKLY ESTIMATE DOCUMENT

Estimate of Construction
SR 500-CR 339A to Bronson
Contract Number 21479
Project Number: 210374-1-52-01
Week Ending: 07/21/2002

Item Description	Item Number	Plan Qty	Weekly Increase	Previous QTD	Quantity To Date	Unit Price	Total	
MOBILIZATION	2101 1	1.00	0.2500	0.5000	0.7500	$356,206.00	$267,154.50	75.00%
MAINTENANCE OF TRAFFIC	2102 1	1.00	0.0000	0.2390	0.321	$72,984.00	$23,427.86	32.10%
SPECIAL DETOUR (DETOUR 1)	2102 2 1	1.00	0.0000	0.0000	0.000	$50,000.00	$0.00	0.00%
OFF-DUTY LAW ENFORCEMENT OFFICER	2102 10	104.00	0.0000	0.0000	0.0000	$30.00	$0.00	0.00%
WORK ZONE SIGNS	2102 60	21,516.00	987.0000	3,048.0000	4,035.0000	$0.28	$1,129.80	18.75%
BUSINESS SIGNS	2102 [illegible]	5.00	0.0000	0.0000	0.0000	$39.00	$0.00	0.00%
BARRIER WALL (TEMP) (F&I)(STANDARD)(CONCRETE)	2102 70 11	904.00	0.0000	0.0000	0.0000	$3.25	$0.00	0.00%
BARRIER WALL (TEMP) (REL)(STANDARD)(CONCRETE)	2102 70 21	602.00	0.0000	0.0000	0.0000	$1.65	$0.00	0.00%
BARRICADE (TEMPORARY)(TYPES I,II,VP & DRUM)	2102 74 1	24,189.00	736.0000	504.0000	1,240.0000	$1.00	$1,240.00	5.13%
BARRICADE (TEMPORARY)(TYPE III) (1800MM)	2102 74 2	7,480.00	0.0000	0.0000	0.0000	$0.40	$0.00	0.00%
PANELS ARROW ADVANCE WARNING	2102 76	55.00	0.0000	0.0000	0.0000	$8.00	$0.00	0.00%
HIGH INTENSITY FLASHING LIGHTS (TEMP - TYPE B)	2102 77	3,542.00	220.0000	608.0000	828.0000	$0.55	$455.40	23.38%
MARKER PAVT REFLECTIVE (TEMPORARY)	2102 78	1,824.00	0.0000	0.0000	0.0000	$2.45	$0.00	0.00%
LIGHTS(TEMP-BARR. WALL MOUNT)(TYPE C STEADY BURN)	2102 79	1,320.00	0.0000	0.0000	0.0000	$0.20	$0.00	0.00%
IMPACT ATTEN VEHIC (TEMP)(REDIRECTIVE OPTION)	2102 89 7	12.00	0.0000	0.0000	0.0000	$2,000.00	$0.00	0.00%
SIGN VARIABLE MESSAGE (TEMPORARY)	2102 99	390.00	0.0000	0.0000	0.0000	$20.00	$0.00	0.00%
PAVT MARKING REMOVABLE (WHITE/BLACK)(SOLID)	2102911 2	176.00	0.0000	0.0000	0.0000	$5.50	$0.00	0.00%
PAVT MARKING REMOVABLE (YELLOW) (SOLID)	2102912 2	276.00	0.0000	0.0000	0.0000	$5.50	$0.00	0.00%
ARTIFICIAL COVERINGS	2104 1	4,735.00	0.0000	0.0000	0.0000	$1.20	$0.00	0.00%
MOWING	2104 4	11.80	0.0000	0.0000	0.0000	$55.00	$0.00	0.00%
HAY OR STRAW BALE	2104 10 1	1,320.00	223.0000	0.0000	223.0000	$4.75	$1,059.25	16.89%
TURBIDITY BARRIER FLOATING	2104 11	240.00	0.0000	141.0000	141.0000	$16.00	$2,256.00	58.75%
TURBIDITY BARRIER STAKED	2104 12	2,230.00	0.0000	393.7000	393.7000	$9.12	$3,590.54	17.65%
SILT FENCE STAKED (TYPE III)	2104 13 1	4,166.00	0.0000	4,100.5000	4,100.5000	$1.84	$7,544.92	98.43%
TRAINEE MANHOURS	2105 70	4,000.00	-379.0000	933.0000	554.0000	$1.00	$554.00	13.85%
CLEARING AND GRUBBING	2110 1 1	1.00	0.0000	0.9000	0.9000	$506,407.00	$455,766.30	90.00%
PAVEMENT REMOVAL OF EXISTING CONCRETE	2110 4	69.00	0.0000	0.0000	0.0000	$15.00	$0.00	0.00%
MAILBOX (F&I) (SINGLE)	2110 7 1	5.00	0.0000	0.0000	0.0000	$80.00	$0.00	0.00%
EXCAVATION REGULAR	2120 1	211,452.00	29,726.0000	152,000.0000	181,726.0000	$3.60	$654,213.60	85.94%
EXCAVATION SUBSOIL	2120 4	20,711.00	0.0000	19,440.0000	19,440.0000	$3.95	$76,788.00	93.86%
EMBANKMENT	2120 6	249,056.00	27,028.0000	195,000.0000	222,028.0000	$3.15	$699,388.20	89.15%
STABILIZATION TYPE B	2160 4	203,998.00	53,687.0000	48,312.0000	101,999.0000	$1.20	$122,398.80	50.00%
BASE OPTIONAL (BASE GROUP M1)	2285701	45,555.00	0.0000	0.0000	0.0000	$5.15	$0.00	0.00%
BASE OPTIONAL (BASE GROUP M9)	2285709	124,900.00	24,792.3500	0.0000	24,792.3500	$7.00	$173,546.45	19.85%
TURNOUT CONSTRUCTION	2286 1	7,091.50	0.0000	0.0000	0.0000	$14.35	$0.00	0.00%
BITUMINOUS MATERIAL (PRIME COAT)	2300 1 1	4,416.00	0.0000	0.0000	0.0000	$0.53	$0.00	0.00%
BITUMINOUS MATERIAL (TACK COAT)	2300 1 3	92,156.00	0.0000	0.0000	0.0000	$0.39	$0.00	0.00%
BITUMINOUS MATL(ASPHALT RUBBER BINDER-INTERLAYER)	2300 1 19	230,710.00	0.0000	0.0000	0.0000	$0.38	$0.00	0.00%
MILLING EXISTING ASPHALT PAVT (20MM AVG DEPTH)	2327 70020	4,686.00	0.0000	0.0000	0.0000	$0.90	$0.00	0.00%
MILLING EXISTING ASPHALT PAVT (40MM AVG DEPTH)	2327 70040	59,400.00	0.0000	0.0000	0.0000	$0.72	$0.00	0.00%
MILLING EXISTING ASPHALT PAVT (100MM AVG DEPTH)	2327 70100	858.00	0.0000	0.0000	0.0000	$4.80	$0.00	0.00%
SUPERPAVE ASPHALTIC CONC (TRAFFIC C)	2334 1 13	39,359.00	0.0000	0.0000	0.0000	$48.00	$0.00	0.00%
ASPH CONC FRICTION COURSE (INC RUBBER)(FC-5)	2337 7 5	9,818.00	0.0000	0.0000	0.0000	$68.50	$0.00	0.00%
ASPH CONC FRICTION COURSE (INC RUBBER)(FC-6)	2337 7 6	74.70	0.0000	0.0000	0.0000	$110.00	$0.00	0.00%
ASPHALT PAVEMENT MISCELLANEOUS	2339 1	280.10	0.0000	0.0000	0.0000	$110.00	$0.00	0.00%
ASPHALT RUBBER MEMBRANE INTERLAYER	2341 70	64,086.00	0.0000	0.0000	0.0000	$0.83	$0.00	0.00%
CONCRETE CLASS I (ENDWALLS)	2400 1 2	97.70	35.3900	26.0000	61.3900	$725.00	$44,507.75	62.84%
CONCRETE CLASS I (MISCELLANEOUS)	2400 1 15	5.00	0.0000	0.5000	0.5000	$400.00	$200.00	10.00%
CONCRETE CLASS IV (CULVERTS)	2400 4 1	471.00	0.0000	191.0000	191.0000	$580.00	$110,780.00	40.55%
REINFORCING STEEL (ROADWAY)	2415 1 1	33,744.00	720.0000	14,295.0000	15,015.0000	$1.05	$15,765.75	44.50%
INLETS (DT BOT) (TYPE E) (<3M)	2425 1551	25.00	7.0000	6.0000	13.0000	$1,265.00	$16,445.00	52.00%
INLETS (DT BOT) (TYPE E) (J BOTTOM, <3M)	2425 1553	1.00	0.0000	0.0000	0.0000	$4,225.00	$0.00	0.00%
INLETS (DT BOT) (TYPE E) (MODIFY)	2425 1559	5.00	0.0000	0.0000	0.0000	$1,750.00	$0.00	0.00%
INLETS (DT BOT) (TYPE H) (MODIFY)	2425 1589	2.00	0.0000	1.0000	1.0000	$3,630.00	$3,630.00	50.00%
MANHOLES (P-7) (<3M)	2425 2 41	2.00	0.0000	1.0000	1.0000	$1,280.00	$1,280.00	50.00%
MANHOLES (J-7) (<3M)	2425 2 71	3.00	0.0000	3.0000	3.0000	$2,930.00	$8,790.00	100.00%
PIPE CONC CULV (CLASS III)(F&I) (750MM CD)	2430 12333	49.40	0.0000	0.0000	0.0000	$157.00	$0.00	0.00%

APPENDIX G

DAILY DIARIES

Daily Diary from Capital Circle Project

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
DAILY REPORT OF CONSTRUCTION

CONSTRUCTION - 04/95
Page 1 of 2

DESCRIPTION OF WORK

CONTRACTOR/~~SUBCONTRACTOR~~: WHITE CONST CO.

OPERATION and LOCATION	TIME BEGINNING	TIME ENDING
- CUTTING SUBGRADE & PLACING TYPE B STABILIZATION & LIMEROCK BASE @ EASTERWOOD	7:00 A.M	7:30 PM
- CONTINUING TO PLACE & COMPACT 2ND LIFT OF LIMEROCK BASE LFT. STAS 590+00 & 599+00 RT.		
- SURVEY & LAYOUT		
- [illegible] IN PREPARATION FOR SETTING CURB INLETS		
- HAULING EXCAV FROM EASTERWOOD CUT TO 635+00-639+[illegible]		

PERSONNEL	NO.	HOURS WORKED	MATERIALS RECEIVED
SUPT.	1	12	- LIMEROCK BASE FROM GARBAGE [illegible]
FOREMAN			
SKILLED	7	12 EA.	
SEMI SKILLED			
COMMON	5	12 EA	
TRAINEE			

EQUIPMENT (ACTIVE/IDLE)

A	I		A	I		A	I		A	I	
		AIR COMPRESSOR			CULTIPACTOR			POWER BROOM	10		TRUCK, DUMP
		AIR HAMMER			DRAGLINE			PUMP			TRUCK, FLATBED
	1	ASPHALT PAVER	1		EARTH MOVER	1		ROLLER,STEEL WHEEL	1		TRUCK, GREASE
		ASPHALT DISTRIBUTOR	2		FRONTEND LOADER			ROLLER,TRAFFIC			TRUCK, LANE STRIPING
2		BACKHOE TRACK			HAND LINER		1	ROLLER, VIBRATORY	3		TRUCK, PICKUP
2		BULLDOZER			HARROW			ROTARY TILLER/MIXER			TRUCK, WATER
		CONCRETE BUCKET			GENERATOR			SPREADER, BOX			WELLPOINT SYSTEM
		CONCRETE SAW		1	MECHANICAL TAMP			SPREADER, SEED	1		RT HOE
		CONCRETE SCREED			MILLING MACHINE			SPREADER, FERTILIZER			
		CONCRETE VIBRATOR	2		MOTOR GRADER			TRACTOR, FARM			
		CRANE, CRAWLER			MULCHER			TRANSPORT			
		CRANE, TRUCK			PILE DRIVER & HAMMER			TRUCK, BUCKET			

CONTRACT QUANTITY INCREASES TODAY (ESTIMATED ☐, ACTUAL ☐)

ITEM NO.	ITEM	QUANTITY	REMARKS AND CALCULATIONS
1-285709	LIMEROCK BASE BASE-OPTIONAL (BASE GROUP 09)	— SY	WORK IN PROGRESS
1-160-4	STABILIZATION TYPE B	— SY	WORK IN PROGRESS

STATE JOB NUMBER:	F.A. JOB NO.:	CONTRACT NO.:	DATE:	DAY OF WEEK:	CONTRACT DAY NO.:
21968915201 55003-3517	ACXA-446-1-(34)	19849	4-2-98	THURSDAY	190

DISTRIBUTION: ORIGINAL - PROJECT FILE
COPY - CONTRACTOR (AS REQUESTED)
COPY - DISTRICT CONSTRUCTION ENGINEER
COPY - CENTRAL OFFICE RECORDS CONTROL
COPY - FHWA (F.A. OVERSIGHT)

Page 1 of 6

APPENDIX H

ASPHALT PAVING REPORT

Asphalt Report from SR-26 Project

DAIL REPORT OF ASPHALT PAVING INS TOR

Fin. Project ID 207759-1-52-01 Mat'l. No. 123D Sample No. 32C073 Date Sampled 01/03/03

Station From 40+00 Station To 41+85 Rdwy Side R Mainline Y

at Line 3'L RT. RDWY Source 05 Plant No. A02/2 Quantity (SY/SM or Tons/MT)

Intended Use ASPHALT BASE (BASE GROUP 13) Date Tested 01/03/03 Tested By Code ZE

PAY ITEM	STATUS - Circle One
1 2 2 8 5 7 1 3	NA Passed FA (Failed, penalty Assessed)

Nuclear Gauge No. — Standard Count — LOT No. 2 Type of Mix SP-12.5 (TL-C)

Underlying Course 1st LIFT ASPHALT BASE (75mm) Mix Design No. SP02-1999A ~~Lab Density~~ / Gmm 2.291

Control Strip No. — Control Strip Density — Lift No. 2 Of 3 Control Strip Correction factor —

Lane	Station to Station		Loads	Lin. Ft./M	Ln. Width	SY/SM	Tons/MT	Spread
TURN OUT (RT)	41+52	41+85	12,16,19	33	VARIES	332.05	50.68	152.6
R-2	41+45	40+00	35-38	145	VARIES (5)	384.50	64.42	167.5
						716.55	115.10	

Density Acceptance: TOP ROW - Station and lane of each test BOTTOM ROW - Nuclear density reading or Core specific gravity (Gmb)

							LOT Density / Gmb	%CS / %Gmm	% Pay
41+05 (R-2)	40+73 (R-2)	40+37 (R-2)							
2.311	2.307	2.256					2.291	93.2	100

Length of LOT 145 m Spread Rate 160.6 kg/m²

RECORD OF BITUMINOUS MATERIALS

CONTRACT NO ______ TABLE NO ______ INVOICE NO ______

PAY ITEM NO	1-2300-1-3			
GRADE OF ASPHALT	RS-1			
FOOT CALIBRATION TANK NUMBER	2511			
BEGINNING INCH / MM	24/00			
GALLONS / LITERS	827.0			
ENDING INCH / MM	23/00			
GALLONS / LITERS	673.0			
TIME OF DAY AFTER UNLOADING	4:45 AM PM	AM PM	AM PM	AM PM
TEMPERATURE	66 °C °F	°C °F	°C °F	°C °F
NET (HOT) GALLONS / LITERS	582.95			
CORRECTION FACTOR	.9780			
GALLONS / LITERS @ 60°F / 15°C	570.13			
SY / SM COVERED	2477.05			
SPREAD RATE GAL/SY / L/SM	.23			

TEMPERATURES		
ESTABLISHED	SEE PAGE #1	°F / °C
AVERAGE		°F / °C
MAXIMUM		°F / °C
MINIMUM		°F / °C
AVERAGE of FIRST 5 LOADS		°F / °C

PAVING COMPLETED		
Measured in	Tons / MT	SY / SM
Previous Quantity	3486.34	5968.25
This Quantity	115.10	194.84
Total	3601.44	6163.09
Rejected/Waste	-0-	

Project Engineer: ______

Resident Asphalt Engineer: ______

Inspector: D. Davis

REMARKS: SEE REPORT SAMPLE # BZC04A FOR MEASUREMENTS OF TURNOUT (41+52 TO 41+85) - (41+75 % STATION)
NO DENSITY REQUIRED ON TURNOUT. 132.02 M² USED FOR 0.7 M CURB PAD (INCLUDED IN C OF CURB)
716.55 - 132.02 = 584.53 / 3 LIFTS = 194.84 M²

RECYCLED PAPER

APPENDIX I

COST DATA

COMPLETED PROJECTS: LIMEROCK BASE

I-95

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 8	2285708	139,606.00	SM	$7.97
Base option 12	2285712	166,385.00	SM	$10.74

Capital Circle

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 4	2285704	2,740	SM	$5.26
Base option 9	2285709	15,570	SM	$6.65
Base option 16	2285716	87,875	SM	$8.58

SR-500

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 1	2285701	45,555.00	SM	$5.15
Base option 9	2285709	124,900.00	SM	$7.00

COMPLETED PROJECTS: HMA BASE

SR-207

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 12	2285712	47,418.00	m^2	$14.26

Capital Circle

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 6	2285716	5,333	SY	$4.85
Base option 10	2285710	7,189	SY	$7.27
Base option 13	2285713	69,477	SY	$9.70
Base option 14	2285714	197	SY	$10.50

US-441

Item description	Item Number	Plan Qty	Unit	Unit price
Base group M1	2285701	10,370.00	M2	$4.87
Base group M15	2285715	16,953.00	M2	$13.60
	2285715 A	30,312.00	M2	$15.34

Active Projects: LIMEROCK BASE

SR-26 (Alachua)

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 1	2285701	28,286.00	m^2	$3.90
Base option 9	2285709	93,218.00	m^2	$7.20

SR-20 (Alachua)

Item description	Item Number	Plan Qty	Unit	Unit price
Base option1	2285701	21,167.00	m^2	$7.95
Base option 6	2285706	76,593.00	m^2	$7.00

JAX Airport Access Road

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 1	2285701	10,136.00	m^2	$5.39
Base option 10	2285710	63,345.00	m^2	$10.61

ACTIVE PROJECTS: HMA BASE

SR-26

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 13	2285713	45,418.00	m^2	$18.60

SR-20 (Putnam)

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 1	285701	552.00	Ton	$60.00
Base option 15	285715	86,000.00	Ton	$48.00

I-10

Item description	Item Number	Plan Qty	Unit	Unit price
Base option 1	285701	194.00	SY	$16.00
Base option 4	285704	134,865.00	SY	$9.90
Base option 6	285706	15,573.00	SY	$12.30
Base option 9	285709	23,816.00	SY	$14.75
Base option 10	285710	26,581.00	SY	$16.00
Base option 11	285711	184,912.00	SY	$17.20

APPENDIX J

PRODUCTION DATA FOR HMA BASE CONSTRUCTION

SR-26

Work day	Date	lift	Surface Area	QTY	Note	Factor	Work hour	Actual WH	Productivity
		Daily Quantity				Work Hours			
1	11/22/02	1/3	820.20	2,460.60			10	10	82.02
2	12/2/02	1/3	809.97	2,429.91			10	10	81.00
3	12/11/02	1/3	763.52	2,290.56			10	10	147.51
		1/3	711.55	2,134.65					
4	12/12/02	2/3	969.49	2,908.47			10	10	107.00
		1/3	100.51	301.53					
5	12/26/02	1/3	292.48	877.44			10	10	55.53
		1/3	262.83	788.49					
6	1/2/03	1/3	184.50	553.50			10	10	18.45
7	1/3/03	1/3	33.13	99.39			10	10	173.24
		1/3	1,020.07	3,060.21	1st				
		2/3	194.84	584.52	2nd				
		2/3	484.40	1,453.20	2nd				
8	1/6/03	1/3	713.50	2,140.50			10	10	208.84
		1/3	195.15	585.45	incl T.L				
		2/3	1,179.78	3,539.34	2nd				
9	1/7/03	2/3	415.80	1,247.40	incl T.L, 2nd		10	10	178.45
		2/3	1,368.70	4,106.10	2nd				
10	1/8/03	2/3	819.73	2,459.19	2nd		10	10	97.62
		2/3	57.00	171.00	2nd, T.L				
		3/3			3rd, R-1 & Center turn				
		3/3	99.47	298.41	R-1 & R-2				
11	1/14/03	1/3	416.43	1,249.30	1st		10	10	66.16
		2/3	245.17	735.50	2nd				
12	1/15/03	2/3	464.08	1,392.24	2nd		10	10	59.13
		3/3	127.20	381.60	3rd, R-1 & Center turn				
13	1/20/03	3/3		844.80	1/2 R-1 & 1/2 R-2		10	10	176.10
			795.20	1,540.80	1/2 R-1 & 1/2 Center				
		3/3	965.80	2,897.40	3rd, 1/2 R-1 & turning lane				
14	1/21/03	1/3	1,151.53	3,454.59	1st		10	10	149.29
		2/3	341.33	1,023.99	2nd				
15	1/22/03	2/3	752.53	2,257.59	2nd	0.332	10	3.32	226.67
16	1/27/03	2/3	57.67	173.01	2nd	0.027	10	0.27	213.59
17	1/30/03	3/3			3rd, 1/2 R-1 & 1/2 R-2	0.192	10	1.92	267.41
		3/3	305.53	916.59	3rd, 1/2 R-1				
		3/3	207.90	623.70	3rd, 1/2 R-1 & 1/2 R-2				
18	1/31/03	3/3			3rd, 1/2 R-2	0.868	10	8.68	235.43
		3/3	1,489.00	4,467.00	3rd, 1/2 R-1 & 1/2 R-2				
		3/3	554.51	1,663.53	3rd, 1/2 R-2				
19	2/3/03	3/3			3rd, 1/2 R-2		10	10	131.98
		3/3	912.89	2,738.67	3rd, Turnout (Rt)				
		3/3			3rd, 1/2 R-1 & Center lane				
		3/3			3rd, Intersection radius				
		3/3			3rd, 1/2 R-1 & R-2				
		3/3	406.87	1,220.61	3rd, Turnout (Rt)				
20	2/5/03	3/3	52.47	157.41	3rd, R-2	0.023	10	0.23	228.13
21	2/12/03	3/3	42.50	127.50	3rd, Turnout (Rt)	0.159	10	1.585	26.81
22	3/12/03	3/3		3,250.80	3rd, R-1	0.925	10	9.25	117.15
		3/3	1,083.60		3rd, R-2				
23	3/13/03	3/3	64.93	194.79	3rd, Turnout (Rt)	0.049	10	0.49	132.51

SR-26 (CONTINUED)

		Daily Quantity				Work Hours			
Work day	Date	lift	Surface Area	QTY	Note	Factor	Work hour	Actual WH	Productivity
24	3/28/03	1/3	18.22	54.66	1st		10	10	5.47
		2/3	18.22	54.66	2nd				
		3/3	18.22	54.66	3rd, SW & NW corner				
25	4/28/03	1/3	1,259.63	3,778.88			10	10	125.96
26	4/29/03	1/3	1,747.86	5,243.57			10	10	209.54
		2/3	347.50	1,042.10					
27	4/30/03	1/3	349.54	1,048.62			10	10	118.87
		2/3	839.16	2,517.48					
28	5/1/03	2/3	1,343.85	4,031.55			10	10	134.39
29	5/2/03	2/3	770.76	2,312.27			10	10	77.08
30	5/5/03	2/3	58.47	175.40	Cross-over	0.014	10	0.14	417.64
31	5/14/03	3/3	1,185.80	3,557.40	L-1	0.925	10	9.25	128.19
32	5/15/03	3/3		100.00	L-1		10	10	152.69
				3,554.70	L-2				
				759.70	Turn Lane				
			1,526.91	166.32	X-over				
33	5/16/03	3/3		212.65	X-over		10	10	55.97
				515.10	Turn Lane				
				291.66	Turn out				
				150.16	Turn out				
				234.52	Turn out				
			559.70	275.00	Intersection CR-235				
34	5/21/03	3/3	94.36	94.36	Intersection CR-235	0.369	10	3.69	25.57
35	6/6/03	1/3	1,627.88	4,883.63			10	10	162.79
36	6/9/03	1/3	1,586.80	4,760.40			10	10	158.68
37	6/10/03	1/3	463.73	1,391.18			10	10	150.97
		2/3	1,045.93	3,137.80					
38	6/11/03	2/3	1,470.50	4,411.50			10	10	147.05
39	6/12/03	1/3	13.67	41.00			10	10	241.22
		2/3	1,071.38	3,214.15					
		3/3		840.75	L1 & Center				
			1,327.15	486.40	L1 & L2				
40	6/13/03	3/3		2,190.14	L1 & L2		9	9	92.19
			829.74	324.49	Turn out				
41	7/2/03	1/3	1,212.75	3,638.25			10	10	121.28
42	7/3/03	2/3	413.00	1,239.00			4	4	103.25
43	7/7/03	2/3	840.67	2,522.00		0.563	10	5.63	149.32
44	7/17/03	3/3		5,277.57	L1 & L2	0.948	10	9.48	185.57
					L1				
					L1				
					L1 Rad				
			1,759.19		L2				
45	7/18/03	3/3	435.02	1,305.05	L2	0.137	10	1.37	317.53
46	7/21/03	3/3	18.00	54.00	Center		10	10	1.80
47	7/23/03	3/3	77.00	231.00	Turnout		10	10	7.70
48	7/29/03	3/3		1,811.02	L1		10	10	97.91
			979.07	1,162.20	L2				
49	7/30/03	3/3		373.23	L2		10	10	30.11
			301.08	530.00	Turn Lane				

I-10

		Daily Quantity					Work Hours			
Work day	Date	lift	Qty	Surface Area (SY)	Surface Area (SM)	Base option	Factor	Work hour	Actual WH	Production rate
1	3/31/03	1/3	12,896.00	4,299.20	3594.68	711		11	11	326.79
2	4/1/03	1/3	810.67	270.22	225.94	711		12	12	18.83
		2/3	6,666.66	2,222.20	1858.04	711				
		2/3	4,000.00	1,333.32	1114.83	711				
		3/3	2,993.33	997.77	834.26	711				
3	4/2/03	3/3	7,566.67	2,522.20	2108.88	711		10	10	210.89
4	4/7/03	1/3	429.34	144.89	121.15	711		4	4	30.29
5	4/11/03	3/3	3,193.33	1,064.34	889.92	711		7	7	252.14
		2/3	3,140.00	1,046.56	875.06	711				
6	5/10/03	1/3	6,729.33	2,220.68	1856.77	711		8	8	232.10
7	5/12/03	3/3	6,660.00	2,197.80	1837.64	711		10	10	368.08
		2/3	6,680.00	2,204.40	1843.16	711				
8	8/18/03	1/3	4,315.56	1,438.52	1202.79	711		10	10	283.86
		1/3	5,869.14	1,956.38	1635.78	711				
9	8/19/03	2/3	1,512.63	504.21	421.58	711		8	8	154.00
		1/3	2,907.87	969.29	810.45	711				
10	8/20/03	2/3	4,289.76	1,429.92	1195.60	711		10	10	186.15
		1/3	2,389.08	796.36	665.86	711				
11	8/21/03	2/3	6,666.00	2,222.00	1857.87	711		11	11	252.94
		2/3	3,317.01	1,105.67	924.48	711				
12	8/24/03	3/3	3,888.51	1,296.17	1083.76	711		10	10	108.38
13	8/25/03	3/3	5,330.04	1,776.68	1485.53	711		11	11	215.82
		3/3	3,187.68	1,062.56	888.44	711				
14	8/26/03	3/3	3,333.30	1,111.10	929.02	711		10	10	92.90
15	8/27/03	1/3	5,400.00	1,800.00	1505.03	711		11	11	136.82
16	9/2/03	1/3	2,491.11	830.37	694.30	711		10	10	169.04
		2/3	3,574.11	1,191.37	996.14	711				
17	9/3/03	2/3	4,454.66	1,484.89	1241.55	711		10	10	242.24
		3/3	4,237.00	1,412.33	1180.89	711				
18	9/5/03	3/3	3,200.44	1,066.81	891.99	711	0.487	10	4.87	183.16
19	9/8/03	1/3	198.44	66.15	55.31	711	0.093	12	1.116	165.46
		3/3	464.11	154.70	129.35	711				
20	9/10/03	3/3	52.77	17.59	14.71	711	0.005	11	0.055	267.41
21	9/19/03	1/3	506.70	168.90	141.22	711		10	10	168.11
		1/2	1,523.90	761.95	637.09	704				
		1/2	2,159.40	1,079.72	902.78	704				
22	9/26/03	3/3	506.70	168.90	141.22	711		8	8	105.23
		4/4	2,513.69	837.90	700.59	711				
23	9/29/03	1/3	1,956.20	651.93	545.10	711		10.5	10.5	75.29
		4/4	880.50	293.50	245.40	711				
24	9/30/03	2/3	2,037.30	679.10	567.81	711		11	11	103.24
		3/3	2,037.30	679.10	567.81	711				
25	10/2/03	3/3	497.73	165.91	138.72	711		4	4	34.68
26	10/14/03	4/4	2,730.60	910.20	761.04	711		8	8	95.13
27	10/16/03	4/4	7,717.30	2,572.43	2150.88	711		10	10	215.09
28	10/17/03	4/4	5,361.95	1,787.32	1494.42	711		11	11	135.86
29	10/18/03	4/4	4,511.39	1,503.80	1257.37	711		8	8	157.17
30	10/20/03	4/4	3,488.47	1,162.82	972.27	711	0.350	11.5	4.025	241.56
31	10/22/03	3/3	1,444.44	481.48	402.58	711		11	11	43.77
32	11/10/03	1/3	5,280.10	1,759.83	1,471.44	711		12	12	187.34
		2/3	2,786.67	928.80	776.60	711				
33	11/13/03	1/3	293.33	97.77	81.75	711		10	10	163.49
		3/3	2,554.44	851.39	711.87	711				
		2/3	3,018.89	1,006.20	841.31	711				
34	11/14/03	2/3	3,902.22	1,300.61	1,087.48	711		10	10	218.66
		1/3	2,213.33	1,314.49	1,099.08	711				

SR-20 (PUTNAM COUNTY)

		Daily Quantity					Work Hours			
Work day	Date	lift	Qty (SY)	Qty (SM)	Surface Area (SY)	Surface Area (SM)	Factor	Work hour	Actual WH	Production rate
1	9/12/03	1/3	4,577.79	3,827.62	1,525.93	1275.87	-	11.5	11.5	110.95
2	9/13/03	1/3	3,963.05	3,313.61	1,321.02	1104.54	-	8	8	138.07
3	9/15/03	1/3	706.11	590.40	235.37	196.80	-	9	9	189.48
		1/3	5,412.37	4,525.43	1,804.12	1508.48	-			
4	10/2/03	1/3	2,097.54	1,753.81	699.18	584.60	-	9	9	64.96
5	10/3/03	1/3	4,413.73	3,690.44	1,471.24	1230.15	-	9	9	136.68
6	10/9/03	1/3	3,805.00	3,181.46	1,268.33	1060.49	-	9	9	117.83
7	10/16/03	1/3	541.33	452.62	180.44	150.87	-	9	9	110.84
		1/3	3,038.00	2,540.15	1,012.67	846.72	-			
8	10/27/03	1/3	6,534.64	5,463.79	2,178.21	1821.26	-	9	9	202.36
9	10/28/03	1/3	2,813.87	2,352.75	937.96	784.25	-	9	9	87.14
10	10/29/03	1/3	3,429.66	2,867.63	1,143.22	955.88	-	9	9	106.21
11	10/30/03	1/3	3,084.09	2,578.69	1,028.03	859.56		9	9	95.51
12	10/31/03	1/3	3,456.09	2,889.73	1,152.03	963.24		9	9	107.03

APPENDIX L

CE&I COST: FLORIDA STATEWIDE CCEI SALARY RATE

Florida Department of Transportation

Statewide CCEI Salary Rate

Title	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	Statewide		
									Average	High	Low
Senior Project Engineer	$38.91	$40.30	$35.00	$40.50	$38.58	$38.13	$38.01	$40.63	**$38.76**	**$40.63**	**$35.00**
Project Adminstrator (formerly knows as Project Engineer)	$36.57	$30.42	$29.43	$32.48	$29.85	$30.88	$32.77	$31.28	**$31.71**	**$36.57**	**$29.43**
Contract Support Specialist (formerly known as Office Engineer)	$23.23	$20.95	$23.89	$24.65	$23.03	$26.13	$22.57	$25.55	**$23.75**	**$26.13**	**$20.95**
Office Manager	$14.58	$18.02			$14.21			$18.84	**$16.41**	**$18.84**	**$14.21**
Senior Inspector	$22.89	$22.69	$19.75	$23.00	$20.89	$23.66	$22.04	$22.14	**$22.13**	**$23.66**	**$19.75**
Senior Inspector - BRDG		$22.57		$24.13		$23.52		$24.42	**$23.66**	**$24.42**	**$22.57**
Inspector	$19.13	$18.62	$17.95	$18.25	$17.59	$20.24	$17.76	$18.20	**$18.47**	**$20.24**	**$17.59**
Inspector - BRDG		$20.19		$20.43				$20.02	**$20.21**	**$20.43**	**$20.02**
Inspector - Asphalt Plant	$15.88			$19.56		$23.20		$19.68	**$19.58**	**$23.20**	**$15.88**
Inspector Aide	$14.03	$12.27	$10.46	$12.30	$10.76	$13.97	$12.20	$10.75	**$12.09**	**$14.03**	**$10.46**
Secretary/Clerk	$12.75	$13.02	$13.80	$14.76	$12.02	$14.72	$13.95	$14.19	**$13.65**	**$14.76**	**$12.02**