USING CONTRACTOR BID AMOUNTS TO ESTIMATE THE DIFFERENCE BETWEEN NIGHT-TIME AND DAY-TIME PRODUCTION RATES FOR HIGHWAY AND BRIDGE CONSTRUCTION

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN BUILDING CONSTRUCTION

UNIVERSITY OF FLORIDA

2008

To my mother and father for always supporting me in my academic endeavors.

ACKNOWLEDGMENTS

Many different people aided my research. First I thank my parents for supporting me and allowing me to continue with education. Second I thank my committee members (Dr. Edward Minchin, Dr. Esther Obonyo, and Dr. Ralph Ellis). They have been very helpful in assisting me with my research and also helping me form a defined interesting subject. Dr. Minchin has especially been helpful introducing me to the topic of night-time construction, and without him this research project would not have been possible. I would lastly like to thank the state of Florida Department of Transportation. All eight districts have been incredibly helpful with my study and have responded to every request I have asked of them. I would especially like to thank Debbie Shaw, Pete Nissen, and Angela Woody for guiding me through the inner workings of the Department of Transportation, and gaining me access to their computer system. I am deeply grateful for their efforts.

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December 2008

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Major: Building Construction

Many studies have debated the use of night-time construction work on road construction is the best possible option. Many studies have examined the overall safety of the construction site. Illumination standards, signage requirements, and crash rate data have been studied to determine increased crash rates during night-time hours, as well as the reasons for these crashes. Many such studies focus solely on safety impacts. Few studies have addressed the cost impacts of night-time construction on a project.

Our study used a slightly different approach. We focused more on the different cost impacts of night-time construction on certain types of work throughout the state of Florida: pile driving and asphalt paving.

Many studies that have been performed in the past have focused mainly on the safety impacts that night-time construction creates on the environment. These studies make strong cases that night-time construction significantly increases the amounts of accidents throughout a work zone area. Since relatively convincing evidence has shown that night-time construction is a rather risky operation, this study will focus on justifying whether night-time construction profitability can outweigh the danger it imposes on the work zone. Our study provides the state

of Florida's Department of Transportation (FDOT), with a meaningful guideline as when to perform night construction projects, if at all.

CHAPTER 1
INTRODUCTION

For the most part, night-time construction projects are used on heavier traffic flow areas. These areas may include interstate or state roads that are usually located in metropolitan areas. For this reason not all of the state's Department of Transportation's (DOT's) practice night-time construction, because the need to work at night is simply not there. States such as Florida, California, and Texas highly practice night-time construction. They continue to evolve and strive to better these processes to create a safer and more efficient work environment, while creating a quality product.

It may be surprising to some, but the usage of night-time construction is seen as a highly controversial subject. But what people and civilians do not realize is the fact that there are many different factors that go into place when determining if a night-time project is feasible. Questions such as; is the road a high volume area, where traffic will significantly be impacted by performing work during the day? Which times of the day have the lowest numbers of drivers on this road? What is the size of the construction site and what are the needs as far as illumination requirements are needed to complete the work? What lengths of road can we expect to close at any given time? And are the proper signage and barriers in place during the night-time? All of these items are among the questions that need to be answered before determining to enter into a night work contract.

The presence of night-time construction work can be seen as early as the 1960's. (Ullman 2007) There were many reasons that ultimately led to the decision behind performing work during the night-time. First, by performing the work during the night, construction workers have the opportunity to work during a time period that is much cooler than the day-time. This becomes especially important when construction workers are performing work in southern states

such as Florida and Texas. Secondly, by performing work at night, the construction workers are able to more freely accept material deliveries, as well as perform work that tends to take more space than other processes. The traffic congestion is noticeably lower during the night-time hours and this greatly benefit's the construction crews. Lastly, the presence of night-time construction greatly alleviates the stress that the presence of day-time construction has on the traveling public. If the work were to be performed during the day-time, it would occur during the highest times in commuter traffic. By performing the construction during the night-time, it allows the construction workers to close down portions of the road during a relatively low traffic hour. This benefits both motorists and the contractor.

Although there are many benefits that can be seen by performing road work during the night-time, there are many factors that occur during night-time work that can be seen as detrimental. Ullman performed a study in 2007 that concluded by performing work during the night-time the quality of the work actually suffers. Studies have confirmed that workers who tend to work the long hour shifts, that night work usually demands, have been negatively affected by reductions in their individual sleep times, the amount of undue stress that is placed on the body, and it also greatly affects the workers appetites. Other perceptions are that by working during the night-time will greatly affect the workers reaction time, alertness, and motor skills. It becomes especially important for worker's to be all of the above (alert, have a short reaction time, and have full usage of their motor skills) in order to perform the work both safely and in a quality manner. In actuality these results seen above have not been proven, but it still becomes important to take these factors into account when dealing with night-time construction.

The purpose of this study is to take a look into some commonly performed construction processes that take place on interstate construction jobs. These jobs will include asphalt paving

and pile driving. These items will be studied on projects taking place throughout the state of Florida from the years of 2004-2007. These projects will be separated into projects that occur during the day-time, during the night-time, and projects that occur during the day and during the night. Once these projects have been analyzed they will be averaged and then compared to other similar projects performed during different times of the day as well as the state averages. By comparing the average data to state averages it will allow the researcher the ability to determine if there is a significant difference between the values that were attained by construction projects performed during the night-time and the construction projects performed during the day-time. The general idea is to help prove that there is in fact a noted difference in the costs associated with performing construction during the night compared to the day. Since it is not feasible to manually put researchers on individual projects to determine their production levels, the study will assume that the differences in costs between projects will inevitably reflect the differences in overall productivity between the projects.

CHAPTER 2
LITERATURE REVIEW

Safety Impact of Night-Time Construction

Introduction

One of the more heavily studied factors involving night-time construction is the impact that the construction has on the safety of the project. Proponents of night-time construction argue that there are many items present in night-time construction work that results in it being safer than that of work during the day. For one, night-time construction sites are performed during times when the road has the least amount of drivers on it. It does not take an expert to realize, that with the decreasing number of drivers on the road, there will be less possible cars that will be able to get into a wreck near the job site. Secondly, work can be performed during the night-time when temperatures are lower, this would aid in the overall stamina and alertness of the construction worker on the jobsite. Lastly, by performing certain work processes during the night-time, it gives workers the opportunity of working in much more spacious environments. With the added room that the night offers, workers are able to spread out and perform their work in their own spaces without fear of being injured by other trades (Ullman, Finley, and Ullman 2007).

Even though many believe that by working during the night-time is inherently safer, many experts disagree. Many believe that because of the lack of lighting that is present during the night-time, a construction site actually becomes more dangerous, despite the lack of traffic. In addition experts believes that by narrowing the roadway at a period where illumination is poor, and on average drivers are at their least attentiveness, the worksite is in far more dangerous than it would be while working during the day-time hours.

Assessing the Safety Impact of Night Work in Texas

There have been many studies performed on the subject of safety through out night time projects, including one in the 1980's that took place in California. Researchers studied a number of work sites throughout the state of California and determined that for areas that included active night work zones, accidents increased over the average number of interstate wrecks by 87%. It was furthermore concluded that wrecks increased by 75% when one of the lanes were closed in comparison to no lane that was closed. A similar study conducted in Virginia confirmed the data that was found on the California study, and it further gave credibility to the dangers of night-time construction.

Despite the findings that were uncovered in both the California and Virginia studies there still can be strong arguments for the usage of night-time construction. One could argue that there are actually lower numbers of wrecks that occur during the night than projects that take place during the day. This can be rationalized due to the fact that the lowest amount of drivers travels during the night-time. Even though an increasingly large amount of these drivers get into accidents, there still might be fewer accidents that would occur during the night-time in comparison to the large sample size of drivers that could potentially get into accidents during the day-time. (Ullman, Finley, and Ullman 2007)

Another important study regarding night-time safety took place in Texas between the dates of June 2002 - May 2003. This study broke down a construction site into four different work processes and then determined which processes were the most dangerous and which were the least dangerous. The first work process was demolition and structural repair. This work process was considered to be relatively dangerous because much of the works performed were on overpasses that were above oncoming traffic. Because of the danger associated with this work type, it was determined that this work should be completed during the night-time. The second

work process that was considered was concrete pours. It is common practice to pour concrete during the night-time hours due to the high temperatures that are encountered during the day. The third work process that was studied was paving. Paving entails milling, sealing, and overcoat and much like the other processes mentioned it is more preferred to be performed during the night-time. The last process that was studied was striping. Striping is an extremely slow process. Because of this it only becomes rational that striping be performed during the night in order to reduce the effect that it would have on traffic.

Once the researchers had structured their research project they decided to put it into action and study active work zones throughout the state of Texas. Their studies found that throughout this time period there were 280 active projects. Of these active projects, 39 of them included night work (70% of the 39 projects included night work and day work, and 30% of the 39 projects solely performed night work). The researchers were able to find accident data describing the number of wrecks in or around the work zone area but they were not able to determine if these accidents necessarily happened while the construction site was active. If the researchers were to assume that the work zones were active during each of the accidents than it would be concluded that night-time work greatly increases accident rates on the interstate (Table 2-1).

By further analyzing their data the researchers determined a number of things. First they determined that inactive work zones only experience a slightly higher accident rate than do non work zone areas. In work zones that were active during the day-time, the research found that the average crash rate increased by 36.5%.

After determining the effects of active and non active work zones on crash rate data for day-time projects the researchers decided to perform the same study for projects during the

night-time. This research found that for non active work zones received a 45% increase in annual accidents. For projects that had currently active night work zones, the accident rate ballooned to a 102% increase. After analyzing the data it becomes pretty clear that night work areas have a pretty drastic effect on the safety of the overall project. Lastly once the data was thoroughly studied it was proven that the most dangerous item of work during a night work construction project is resurfacing. While resurfacing projects were underway throughout the state of Texas, accidents spiked by 55.4% (Ullman, Finley, and Ullman 2007)

After looking at the previous studies a very strong case can be made that night-time construction is inherently risky. Because of this, it is important to properly illuminate and barricade the projects to ensure the maximum amount of safety is given to the drivers on the road as well as the workers inside the work zone. The loss of one life is too much. Data suggests that 100 workers die annually in roadway construction related accidents, while another 20,000 are injured. Vehicles and equipment that are currently working inside the active work zone or are currently are passing by the work zone account for over half of the total fatalities. Measures have been taken in the form of increased usage of flagger stations as well as the improved quality that state's Department of Transportation are requiring as far as lighting is concerned. It has begun to make a difference in that less than half of the overall construction deaths that have included being struck by vehicles, have happened from cars coming from the road into the work site.

Department of Transportation State Specification

Methodology

To reiterate, night-time construction has only been a legitimate option since the 1960's. Since that time some states have warmed to the idea while other states have not. For the most part, states that have a high volume of metropolitan areas or interstate highways are more comfortable with night-time work than are states that reside in more rural areas. Nevertheless my

first study on the subject of night-time construction was to come in contact with each construction office of each individual states department of transportation (including Washington D.C. and Puerto Rico). Once I came in contact with someone who was familiar with the inner workings of night-time work procedures I began to ask them a series of five questions.

- Does your state's department of transportation do anything special regarding night-time construction? If so then what do they do?
- Does your state have a specification book that solely deals with night-time construction? Or does your state have an item in your specification book that solely deals with night-time construction?
- Does your state have any specifications for illumination?
- Other than illumination what else can be found in the specification book regarding night-time work?
- Can the specification book be found online?

Once these questions were answered the data was put into a table and analyzed to better determine the overall feeling that the nation has towards night-time work construction.

Trend Analysis

Once the data was analyzed it became apparent that there were a number of trends that could be seen between states. The first trend that was noticed was that all states perform night-time construction in some manner. To clarify there are state's with higher populations such as California, New York, Florida etc… that consistently have night-time construction projects, while states with lower populations such as North Dakota, South Dakota, Montana etc… rarely perform night-time construction because there is simply no need to.

The second trend that can be noticed from the study is that nearly half of the states, 25 of the 52, interviewed had some sort of specification book dealing with night-time construction. This was the most important item of the study. It is important for states that perform construction processes during the night to have a well defined specification book to draw from. The more well defined the specification book becomes, the less confusion that will be present on the jobsite, and

this should lead to a potential decrease in accidents while on the job. These items were analyzed to determine to which extent states have night-time specifications (Table 2-2)

The third trend that was noticed throughout the study was the overall importance that was placed on illumination standards. Illumination standards were the overall dominating feature in contractor's specification books as well as contractor's plans. Of the 25 states that had night-time specs, 24 of them have individual specs dealing with the specific illumination standards that should be present on the jobsite. (with Kansas being the lone exception of states that have specifications but not illumination specifications) States have realized the overall importance that lighting has on the productivity, quality, and safety of the construction site. After conducting the interviews it became apparent that even for state's that might not have had individual specifications dealing with night-time work, they still had specific plans in place mandating the usage of ample lighting by contractors.

One interesting state that should be taken note of is Alaska. Alaska particularly needs illumination specifications. If not already known, Alaska witnesses the night for long expanses of the year, so it is most important for them to have illumination specifications more than any other state because they are almost forced to work during the night. Alaska mandates that there be specific balloon lighting throughout the project as well as also mandating different forms of lighting depending on the machinery and work that is to take place during the project.

It has already been stated that 96% (24/25) of the states that had specification books dealing with night-time construction had a spec dealing with illumination. This is far and away the most controlling item of interest of each state's spec book. Only 64% (16/25) of these states had anything else in their spec book involving any other item of work. One of these items includes the usage of retro reflective gear and flagger stations. States adhere strictly to the

guideline put in place by the MUTCD (Manual on Uniform Traffic Control Devices). The MUTCD requires that flagging stations and workers wear the necessary ANSI rated two or three level vests. This allows flaggers and workers for that matter to be clearly seen by oncoming traffic. Once these workers are seen by oncoming traffic, there is a lesser chance that will be struck by or injured by the oncoming cars.

The next item that was commonly used by state's departments of transportation was the usage of lane closure standards. There are six states that have something written in their specifications solely dealing with lane closure standards. These states include Florida, Illinois, Massachusetts, Nebraska, Oregon, and Virginia. These states have specific plans in place in order provide lane closures in times where the traffic levels are currently low and can be managed.

The third most prevalent item in state's spec books are the usage of signage. Signage becomes important to help prepare the driver to when there will be construction coming. This allows drivers to explore alternate routes to their destination, which is a benefit to both the driver and the contractor. If they are not able to find a secondary route, it allows the driver to slow their car down before driving through a dangerous zone, to prevent accidents. These states that have specifications dealing with signage include Connecticut, Florida, Nebraska, and New York.

Guardrails and state troopers were the last two items that were mentioned through out the interview. Guardrails being used obviously for protection for workers inside the work zone area. State troopers were to be used to help enforce the authority of safe driving and behavior throughout the work zone area.

In al this study proved that there is still much to be done in the way of planned development of night-time construction. Less than half of the states interviewed had

specifications dealing with night-time construction and that is far too low. Hopefully in time better plans will be formulated and adopted by each state, in order to ensure a safer working environment.

To conclude the study, a table was organized to fully show which states have their night-time specifications on the internet (Table 2-3).

Plan and Prevention

Since it has been shown in one of the more recent studies that it is more than 85% likely to get into an accident when night work construction is taking place, many experts decided to find a way to manage the dangers on night-time construction projects and develop a traffic management system (Anderson and Ullman 2000). This study hoped to develop a system which can notify drivers where alternate routes may be. This would reduce the amount of traffic on the road at the time of construction, which would inevitably lead to fewer wrecks. Much to their amusement, studies have shown that motorist will typically take alternate routes when they are provided to them instead of having to drive through an active work zone.

To develop this traffic management program the researchers had to keep a number of items in mind. They had to be aware of the economic impacts the construction would create, the impact it would have on safety, the overall public's point of view on the construction, as well as keep in mind the overall traffic strategies of the project.

The first matter of business that should be considered when determining a traffic management is the economic impact it will have. While implementing one of these plans, contractors are able to install a number of surveillance equipments. The items may include closed circuit televisions, inductive loop, radar, microwave, and other vehicle detectors. This would allow the team to study and determine which are the best times to perform the projects, as well as closely monitor the items of severe consequence. The traffic management system also

has the ability to notify the oncoming public by improving traffic signals as well as Traveler Information Systems that include highway advisory signs and stations, kiosks, radio stations, etc… This is a decision that the department of transportation must make while they are deciding on the course of action they will take. On larger sized projects it might be a good idea to spend the money and make sure that the project is well run because the impact of an accident could be much greater. (Anderson and Ullman 2000)

In many states the decision has been to cut cost and to have many different tradesmen work in the same active work zone. This will minimize the amount of time that there will be lane closures, but it can also be assumed that it increases the risk of accident within the site due to the amount of simultaneous work taking place. It also reduces the cost to the motorist who is impacted by traffic delays by the cost of $10-$13 per hour. (Anderson and Ullman 2000)

The next thing that must be taken into account while developing a traffic management plan is the safety impact it will have. Throughout the United States, each state's department of transportation is beginning to develop its own specification book dealing with night-time construction. The most important of these specification items would be illumination standards. Currently the MUTCD requires that retro reflective vests be worn by workers and that there must be flagging stations around dangerous work items. Also, contractors and the department of transportation are working together to determine what the specifications for lighting should be for individual items of work, while at the same time determining what the allowable glare rating is to be for oncoming traffic. (Glare is important because it can impair the sight of the oncoming traffic)

The third item that must be taken into account would be the perception of the public. A construction process should be performed in different ways depending on the geographical

location. For instance, if a construction process is currently located in or near a residential neighborhood maybe the usage of night-time construction would not be the best choice. Families enjoy their peace and privacy during the night-time hours. The same can be said for performing construction work in front of businesses. Businesses would prefer for the work to be done during the night-time, so as not to deter customers from coming during the day. It is very important to take the public's perception to heart. (Anderson and Ullman 2000)

The last thing that should be taken into account is the different traffic handling strategies. There are many different ways that a contractor can optimize the production on a project while minimizing the amount of traffic. For instance portable concrete barriers and paddle screens allow contractors to become much more mobile when it comes to roadway construction. They can manually place the barriers only at times when work is to be performed. Secondly they could close down entrance ramps that enter into the work zone itself. This will limit the amount of cars that will be driving through the work zone and therefore relieve the amount of stress that traffic imposes onto the construction site. The usage of roadway shoulders as lanes can also help alleviate the stress of traffic by adding an additional lane for through traffic. If this is not a viable option the usage of reversible lane can also be seen as an option. This includes closing down a lane of say the North side of the interstate and allowing South travelers to use that lane while one of their lanes is closed down by construction. Lastly the usage of service patrol to immediately remove and clean up accidents if they do happen would greatly reduce the impact of traffic.

While performing an interstate project it is extremely important to plan the construction process before hand. By planning the project before hand it allows the contractor the foresight to determine which items are profitable and which items are losing money. It also gives the contractor the opportunity of sequencing items, equipment, and labor forces at optimal times to

reduce the amount of unproductive time. The usage of value engineering would be a great addition to the construction planning process.

Once you have considered which kind of impact each of these factors will have on the project a number of items need to be determined in order to develop the traffic management plan. These items can be seen below.

- Type of work
- Encroachment required (storage, buffers, and loading areas)
- Project work limits
- Tentative schedule
- Time periods that the area will be occupied
- Location of the nearest utilities
- Work vehicle entrances and exits.

Once all of these items have been considered the traffic management plan is ready to be developed and implemented. (Anderson and Ullman 2000)

Luminance Detection

While a project is going through the planning stages it first is determined if the project will be performed during the night-time or during the day. If it has been chosen to be performed at night another set of questions must be answered. These questions deal with the usage, amount, and the overall ratings of the lights that are necessary to work on the project. A study was performed to citing the four main factors to consider when determining which kind of lighting to use on the construction project (Ellis, Amos, and Kumar 2003).

The first item that must be considered when developing a proper lighting plan is to determine what kind of work is to be performed on the project. If a project's work zone is a larger than normal area and the item of work being performed in this work zone area is also riskier than normal that it is preferred that the work be performed in a more well lit area. This will provide the workers who are working in the work zone area a more detailed view of the

work that they are performing. Conversely to this example, if work zones are in small areas and the work items that are being performed are rather menial and less risky, ample amounts of lighting might not be necessary. This will not only conserve cost on the project by reducing the amount of lighting towers but it will also reduce the glare to the oncoming traffic, which will in turn reduce the number of work zone crashes. (Ellis, Amos, and Kumar 2003)

The second item that must be considered in determining the amount of lighting on a project would be the overall age of drivers traveling through the work zone area. Studies have proven that the older the driver is, the less reactive that they are to items in their environment. In areas where the average age of drivers is expected to be high, higher levels of illumination should be increased. (Ellis, Amos, and Kumar 2003)

The third item that impacts work zone illumination standards are the average speeds throughout the work zones. Studies have also proven that the faster that drivers travel in their cars the less aware they are of their surroundings. In night-time environments drivers tend to drive at higher speeds for a multitude of reasons. One such reason being that there are fewer people on the road, these promoting faster traveling speeds. In areas where the speed limits are higher drivers are much less aware and therefore more likely to get into accidents. Proper lighting should be adequately adjusted to the speeds of the roads which construction work is being performed. It also might be in the better judgment of the general contractor to either reduce the speed limit through the work zone area and/or employ the services of state troopers to police the speed through the work zone area.

The last item to be considered when introducing lighting plans, are the overall presences of lighting glare that affect the traveling public. While performing construction work on a roadway project during the night, it becomes very important to have ample lighting. Contractors

walk a very fine lighting while determining the amount of lighting that is sufficient enough to perform a construction process without causing potential harm to the oncoming traffic by the likes of glare. It must be determined by the type of work is to be accomplished what is the necessary amount of light needed for a certain item of work. Once this lighting level has been reached, it is also important that this level not be surpassed further endangering the oncoming public.

With the usage of this four point lighting plan contractors can mix and match different needs in order to determine the safest and most productive lighting plan that they can develop. Table 2-4 shows there are a number of different lamps, which are used on the construction sight. In addition to this are the output levels of each of the lamps, the mounting heights, and the types of work that these lamps are used for on the construction site. (Ellis, Amos, Kumar 2003)

Automated DSS Systems

El Rayes and Hyari (2005) developed an automated decision support system (DSS) that would accomplish the four main categories that dealt with night-time construction. Their ideas were to theoretically develop a system that would maximize the amount of light throughout the work zone area, with an evenly distributed beam, while minimizing the amount of glare the light would create to oncoming traffic. Once these factors have been determined the contractor must decide on a DSS system that is the most cost efficient.

Taking these four variables into account, El Rayes and Hyari began developing their lighting plan for their construction project. Their lighting plans consisted of seven different variables (Figure 2-1). (Rayes and Hyari 2005)

Once the contractor has determined the type of work that is being performed, as well as the size of the work zone, he/she can develop a useful lighting plan with the usage of these seven variables.

Signage

Another factor that has been studied with the intention of improving construction work zone safety is roadway signage. Studies have shown that roadway signage plays a great part in the safety of a job site. Treat (1977) said in one of his studies that over 40% of accidents occur from difficulties of perception, attention, and distraction. By improving the awareness of the drivers traveling through the work zone area, contractors can almost reduce the amount of accidents taking place in the work zone by half. Macdonald and Hoffman (1991) went on to further say that limited attention capacity is a large factor in sign recognition. Because of this fact it is imperative that the department of transportation as well as the contractors make the sign easy to read, as well as visually noticeable (by coloring it bright neon colors). (Anders 2000)

To further elaborate on these studies Anders decided to determine if the different colors of signage and the overall attention span of drivers had any effect on the accident rates through work zone areas. To accomplish this study he did a number of things. First he handed out a questionnaire randomly to a number of drivers asking what are the most visually appealing colored signs that the drivers noticed and read. Secondly he studied a number of expanses of road and recorded the number of late braking maneuvers and turn errors that drivers encountered. These two errors are very common with drivers who are not currently aware of their surroundings. (Anders 2000)

Once the data was accumulated and analyzed a number of items were determined. First the majority of late braking maneuvers and turn errors occurred with older drivers. This is consistent with the findings stated earlier by Ellis, Amos, and Kumar, stating that since older people typically have worst eye sight and lower reaction times more lighting should be used if it is expected that many of the drivers traveling at night are elders. Because of this it was

concluded that in areas where older drivers are expected to be the majority of travelers, there should be more illuminated and fluorescent signage.

Anders also determined by the questionnaire, that non fluorescent yellow and non fluorescent purple were the least appealing colors of signage for those driving. Instead both the older and younger groups of drivers preferred black lettering on both a fluorescent yellow and fluorescent green signs. These colors were preferred because the contrast between the fluorescent signs and the black lettering allowed drivers to read the signs easier than the non fluorescent signage would.

To no surprise it was determined that statistically there were more late braking maneuvers and turn errors that occurred during the night than during the day. This data has been consistent with the other studies on the subject, further proving that drivers are less aware of their surroundings during the night.

Anders continued the study in more detail by comparing three different items. The first item was to determine if there were as any differences in driving behavior that occurred by the different colorings of signs (Table 2-5). The second item, studied the same expanse of road, but instead looked at the average age of the driver. This study would not only prove that older people are less aware of their surroundings, but it would also show which color combinations are most noticeable for both younger and older drivers (Table 2-6). The last item compared, was a study that determined to what extent does driving during the day and driving during the night have on a driver's awareness (Table 2-7). (Anders 2000)

This study concluded by showing fluorescent signage is much preferred by drivers on the interstate. These drivers are able to notice the signs quicker and are able to read these signs clearer due to the fact that they glow in the dark. This is not where the benefit of fluorescent

signs ends however. An additional study that took place in North Carolina concentrated on the effect that fluorescent signage had on interstate drivers. This study found that fluorescent orange signage actually affected the behavior of drivers on the road. During this expanse of road, researchers noticed that in areas with these fluorescent orange signs there occurred fewer traffic conflicts, fewer cars driving in the left hand lane, and cars tended to gravitate toward the right lane more often than normal. In addition to all of these things the average speeds of the cars traveling on this road were less normal. (Anders 2000)

In the end it is proven that the usage of fluorescent signage is beneficial to night-time construction. They are more easily read by the drive and they are also far more preferred by the driver as well. The usage of neon signage in the work zone will allow the driver to become fully aware of the situation that lies before them in the work zone, which in turn will hopefully significantly reduce the probability of crashes during construction.

Table 2-1. Assessing the safety impact of active night work zones in Texas

Night work category	Districts with rare night work	Districts with significant night work
Daytime work zone crashes	4,903 Total- 2,987 (61%) Severe	15,806 Total- 10,530 (67%) Severe
Daytime non-work zone crashes	94,652 Total- 63,724 (67%) Severe	250,811 Total- 169,756 (68%) Severe
Nighttime work zone crashes	1,545 Total- 984 (64%) Severe	6,801- 4,214 (62%) Severe
Nighttime work zone crashes	38,707 Total- 23,986 (62%) Severe	100,310 Total- 63,131 (63%) Severe

Table 2-2. Individual state night-time specification list

States	Special nighttime work procedures	Nighttime work specs	Illumination specs	Other requirements in specs	Comments
Alabama	None	No	No	None	Contractor has to perform the work that will be inspected by the DOT
Alaska	Yes	Yes	Yes	None	Specific lighting needed for work processes and machinery. Use balloon lighting
Arizona	None	No	No	None	Only puts disincentive in contract for contractors who do not open by specific times in morning. Uses police for lane closures.
Arkansas	None	No	No	None	Follows the MUTCD strictly. This includes reflective cones and barriers Nothing else is mandatory for night-time construction.
California	Yes	Yes	Yes	(High Visibility Permits, Reflective ANSI 2 Vests)	Items on the jobsite such as cones and barriers must be reflective. Lighting must be to OSHA standards.
Colorado	Yes	No	No	None	There will be special work configurations for night work. There are no specifications; it is more of a state policy.
Connecticut	Yes	Yes	Yes	(Crash Trucks, Signage, and State Trooper Requirements	There are specific specifications for night work. This mostly involves lighting and the other items mentioned.

Table 2-2 (Cont)

States	Special nighttime work procedures	Nighttime work specs	Illumination specs	Other requirements in specs	Comments
Delaware	Yes	No	No	None	Do not necessarily have light specs, but when night work is necessary they use a specific manual. This manual deals with lane closures, lighting necessities, and reflective clothing.
Florida	Yes	Yes	Yes	(Materials, Lane Closures, Guardrails, Signage, etc...)	There is maintenance for traffic and standards to be the same for quality. DOT does lane closure analysis searching for best time.
Georgia	None	No	No	None	The state has made provisions to improve the reflectivity of vests and safety gear.
Hawaii	Yes	No	No	None	Specific areas throughout the state must achieve permits in order to perform work of certain noise levels and lighting levels.
Idaho	None	No	No	None	Idaho has no specifications for night work. When night work is done, provisions are put in the contract.
Illinois	Yes	Yes	Yes	(Traffic Control Standards, Lane Closure Ramps, etc...)	There are details on how lane closures will be set as well as other processes on how to determine lane closure ramps.
Indiana	Yes	No	No	None	This DOT follows the MUTCD. Requires that work sites be illuminated for workers. Also they require reflective vests and gear.

Table 2-2 (Cont)

States	Special nighttime work procedures	Nighttime work specs	Illumination specs	Other requirements in specs	Comments
Iowa	Yes	Yes	Yes	None	Currently the only items in the state of Iowa's specification book relate to lighting standards.
Kansas	Yes	Yes	No	(Materials, Equipment, Reflective Gear)	Illumination standards are up to the contractor to determine how much light is needed to perform the work.
Kentucky	None	No	No	None	This state requires that the OSHA minimums must be met. This includes reflective gear, etc...
Louisiana	Yes	Yes	Yes	(Equipment, Light Meters, Glare Control, Lighting Plan)	All of the items that the state of Louisiana concentrates on deal solely with illumination standards.
Maine	None	No	No	None	Lighting requirements will be decided on a per project basis. There are requirements for reflective gear.
Maryland	Yes	Yes	Yes	None	Lane Closure Standards. Additional signage. Lighting is specific to light operations.
Massachusetts	Yes	Yes	Yes	(Lane Closure Standards and Usage of Drums for Barriers)	Police Troopers may be employed by contractor. Lighting on paving operations required.
Michigan	Yes	Yes	Yes	None	The only thing that the state of Michigan does for night-time work is lighting standards and specifications.
Minnesota	Yes	No	No	None	They adhere to the MUTCD, and all of the requirements for lighting are set out on a project by project basis.

Table 2-2 (Cont)

States	Special nighttime work procedures	Nighttime work specs	Illumination specs	Other requirements in specs	Comments
Mississippi	Yes	Yes	Yes	None	Mississippi has a different set of lane closure standards for day and night-time construction
Missouri	None	No	No	None	Lighting on each project is completely up to the contractor. This state also has some lane closure procedures.
Montana	None	No	No	None	Montana follows the MUTCD guidelines very strictly. They also require lighting on a project specific basis, in which the requirements will be in the special provisions of the contract documents.
Nebraska	Yes	Yes	Yes	(Lighting Signs, Traffic Controls, Reflectivity)	This state has one of the most well defined plans regarding night-time construction.
Nevada	Yes	No	No	None	All of the traffic control meets MUTCD standards. Towers are lit. Boards and press releases warn of lane closures.
New Hampshire	None	No	No	None	This state only follows MUTCD guidelines when performing night work.
New Jersey	None	No	No	None	Illumination standards are completely up to the contractor. DOT has no such specifications.
New Mexico	None	No	No	None	This state does not have any specifications regarding night-time work. This is the contractor's responsibilities.

Table 2-2 (Cont)

States	Special nighttime work procedures	Nighttime work specs	Illumination specs	Other requirements in specs	Comments
New York	Yes	Yes	Yes	(Visibility Requirements and Sign Sheet Signage)	The state requires different areas for night work, different illumination for work processes, and high visibility apparel.
North Carolina	Yes	Yes	Yes	(Reflective Flagging)	The contractor shall provide the items necessary in order to provide the lighting specs
North Dakota	Yes	Yes	Yes	(ANSI 3 Full Reflective Gear)	Night work is very rare but there still are a number of provisions for night work. Most importantly there is lighting standards
Ohio	Yes	Yes	Yes	None	Not in the specifications, there are lane closure maps that are used by the DOT to aid in the flow of traffic during construction.
Oklahoma	None	No	No	None	There are no minimum illumination requirements. Night work illumination is completely up to the contractor.
Oregon	Yes	Yes	Yes	(Reflective Flaggers and Lane Closure Standards)	This state's DOT performs lane closure standards, illumination requirements, etc...
Pennsylvania	Yes	No	Yes	(Work Zone Traffic Control, Taper Lengths)	This state has traffic control specifications that control specs for illumination in the work zone.
Rhode Island	Yes	No	No	None	Follow MUTCD strictly and will inspect contractors lighting plans. Make sure the usage of flaggers and or police depending road size

Table 2-2 (Cont)

States	Special nighttime work procedures	Nighttime work specs	Illumination specs	Other requirements in specs	Comments
South Carolina	Yes	Yes	Yes	None	The state of South Carolina requires the specific usage of lighting as well as the usage of reflective drums as barriers.
South Dakota	Yes	Yes	Yes	(Reflective Flagging)	They require the usage of lighting on the project only
Tennessee	Yes	Yes	Yes	None	The only necessity is the needs for illumination requirements.
Texas	Yes	No	No	None	Texas requires that lighting requirements be based on a per project basis. Each district might make a specific plan regarding night work but it is not in the spec book.
Utah	Yes	Yes	Yes	(Flagger Equipment and Clothing, Reflective Drums)	Utah requires that the usage of lighting and the usage of reflective gear and drums are necessary.
Vermont	Yes	No	No	None	Vermont adheres to a standard of lighting put forth by the FHWA. They do not require there own lighting specification.
Virginia	Yes	Yes	Yes	(Lane Closure Standards, Flagging, State Troopers)	Specification deal with lighting angles, illumination, lane closure standards, flagging, and state troopers.
Washington	Yes	No	No	None	Lane closures are given traffic control plan that contractors may alter. No real lighting spec but concentrate on usage of flaggers.

Table 2-2 (Cont)

States	Special nighttime work procedures	Nighttime work specs	Illumination specs	Other requirements in specs	Comments
West Virginia	Yes	Yes	Yes	None	They use temporary lighting and a new channelizer cone for easier and quicker set up for contractors.
Wisconsin	No	No	No	None	Wisconsin does not do anything special regarding night-time work or illumination requirements. Changes to night work are project specific.
Wyoming	No	No	No	None	All the state requires is that the site is well lit. Engineer makes decision.
Washington D.C.	No	No	No	None	Follows the standards put forth by the MUTCD but does not have a defined spec book dealing with night-time construction.
Puerto Rico	Yes	Yes	Yes	None	Puerto Rico has currently developed an illumination plan dealing with night-time construction.

Table 2-3. State specification list

States	Specification website address
Alaska	http://www.dot.state.ak.us/stwddes/dcsspecs/assets/pdf/hwyspecs/specialprovs/specials_101507.pdf
California	http://www.dot.ca.gov/hq/esc/oe/index.html#standards
Connecticut	http://www.ct.gov/dot/cwp/view.asp?a=1385&q=259494
Florida	http://www.dot.state.fl.us/specificationsoffice/2007BK/102.pdf
Illinois	http://www.dot.state.il.us/desenv/hwyspecs.html
Iowa	http://www.dot.state.ia.us/specifications/dev_specs/DS-01081.pdf
Kansas	http://www.ksdot.org/burConsMain/specprov/2007SSDefault.asp
Louisiana	http://www.dotd.la.gov/doclist.asp?ID=50
Maryland	http://www.sha.state.md.us/businesswithsha/bizStdsSpecs/desManualStdPub/publicationsonline/ohd/Start.pdf
Michigan	http://mdotwas1.mdot.state.mi.us/public/specbook/
Mississippi	http://www.gomdot.com/Divisions/Highways/Resources.aspx?Div=Construction
Nebraska	http://www.dor.state.ne.us/ref-man/specbook-2007.pdf
New York	https://www.nysdot.gov/portal/page/portal/main/business-center/engineering/specifications/specs-repository/Specbook2006TableErrata.pdf
North Carolina	http://www.ncdot.org/doh/preconstruct/ps/specifications/english/2006.html (Gen Specs and Specials Provisions)
North Dakota	http://www.dot.nd.gov/dotnet/supplspecs/StandardSpecs.aspx
Ohio	http://www.dot.state.oh.us/construction/OCA/Specs/2008CMS/2008_ODOT_C&MS.htm
Oregon	http://www.oregon.gov/ODOT/HWY/SEOPL/docs/manuals/specification-manual.pdf
Pennsylvania	http://www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/ConstructionSpecs408and7?readForm
South Carolina	http://www.scdot.org/doing/StandardSpecifications/pdfs/2007_full_specbook.pdf
South Dakota	http://www.sddot.com/Operations/specifications/index2004.htm
Tennessee	http://www.tdot.state.tn.us/construction/Supplemental%20Specs%202006/SS700.pdf
Utah	http://www.udot.utah.gov/main/f?p=100:pg:799439532877892:::1:T,V:1945
Virginia	http://www.virginiadot.org/business/resources/WAPM-2005- Revised10_05.pdf
West Virginia	http://www.wvdot.com/engineering/Specifications/2003/Y2KSpecB.pdf

Table 2-4. Different categories of lamps used on a night-time construction project

Category 1 541x (5 ft candles)	Category 2 1081x (10 ft candles)	Category 3 2161x (20 ft candles)
Lowest quality light Should be used for low accuracy work	Recommended on or around equipment and the visual tasks of these equipments such as resurfacing	Needed for tasks that have higher difficulty and require more light usage.
Slow moving equipment Large sized equipment to be seen		Crack fillings, critical connections and maintenance of electrical devices, or moving machinery

Table 2-5. Frequency of late braking at Woodland Hills sign (#18)

Sign color combination	No late reaction observed	Late reaction observed
Black on fluorescent yellow-green	16	4
Non-fluorescent yellow on non-fluorescent purple	18	3
Black on fluorescent coral	15	5
Fluorescent yellow on fluorescent purple	16	5

Table 2-6. Frequency of late braking at Woodland Hills sign (#18) by age

Sign color combination	Older drivers	Younger drivers
Black on fluorescent yellow-green	2	2
Non-fluorescent yellow on non-fluorescent purple	3	0
Black on fluorescent coral	4	1
Fluorescent yellow on fluorescent purple	5	0

Table 2-7. Frequency of late braking at Woodland Hills sign (#18) by visibility

Sign color combination	Daytime	Nighttime
Black on fluorescent yellow-green	0	4
Non-fluorescent yellow on non-fluorescent purple	1	2
Black on fluorescent coral	2	3
Fluorescent yellow on fluorescent purple	1	4

- **Lighting equipment selection**: determine if need ground mounted towers, trailer mounted towers, and equipment mounted luminaries.
- **Type of lamps**: metal halide lamps, high pressure sodium vapor lamps, halogen lamps, and low pressure sodium vapor lamps.
- **Lamp lumen output**: Represents energy of lamp, influence visual comfort and luminance
- **Mounting Height**: Portable lighting towers are made with adjustable heights up to 25m.
- **Lighting tower positions**: Influences average illuminance and lighting through the site.
- **Luminaries lighting angles**: angle of beam of light and nadir, positioning of lights affect site coverage
- **Lighting tower positioning**: Allow lamps to directed at specific areas instead of having unused lights in non working zones.

Figure 2-1. El Hyari and El Rayes' automated DSS system.

CHAPTER 3
METHODOLOGY

Much has been touched upon as far as the safety impacts that night-time construction has on both the traveling community and the workers inside the construction area. This study is going to concentrate on a slightly different factor that is very important for the department of transportation to take notice of. This study will concentrate on the cost and productivities, in Florida between the years of 2004-2007, that are associated with performing construction during the day-time as well as during the night-time.

This study will focus on five different items. These items include asphalt paving Friction Course FC-6, asphalt paving Superpave Traffic C structural course, asphalt paving Superpave Traffic D structural course, eighteen inch prestressed concrete piles, and twenty four inch prestressed concrete piles.

Since there are different types of asphalt that can be studied, this study will look at the two most popular structural courses of asphalt used during this time period as well as the most popular friction course of asphalt used. Through these four years the most popular items of structural asphalt are Superpave Asphaltic Concrete (Traffic C) and Superpave Asphaltic Concrete (Traffic D). These two items will be quantified individually when analyzing the data at the end of the project.

The last form of asphalt that will be considered will be a friction course. The friction course that was most commonly used in construction for these time periods was Asphalt Friction Course (FC-6). Since both structural courses and friction courses are used on the construction site simultaneously and have different costs it is imperative that these numbers be separated when analyzing the data.

The second item that will be analyzed will be pile driving procedures. These items will be broken into the two most popular forms of piles driven during the four year span. During this span the two most common piles were the eighteen inch square precast concrete column and the twenty four inch square precast concrete column.

This study will be performed by using the state of Florida Department of Transportation website. From there the researcher will access the admin page and come to the bid letting information. The researcher will then manually scan four full years of bid letting information, sorting out the different projects that contain the items stated above; Superpave Asphaltic Concrete Traffic C, Superpave Asphaltic Concrete Traffic D, Asphalt Friction Course (FC-6), eighteen inch square precast concrete columns, and twenty four inch square precast concrete columns.

Once these projects have been sorted they will be entered into a table, to be analyzed at a later date. This table will be separated by the work being performed and by which material is being used. For the asphalt paving procedures the bid letting date will be noted, as well as the project identification number, quantity in tonnage of how much of the material was used, the unit cost per ton, and the contractor who performed the work. At a later date the data will be separated by individual work processes to determine the differences in costs that occurred by the time of day.

The pile driving operations will be documented much the same way that the paving operations were documented. First the individual bid letting information will be scanned to determine the projects that contained pile driving operations. Once it has been determined that a specific project included pile driving, the project will be separated and the necessary data will be recorded. This data will include the bid letting data, the project identification number, the size of

the individual piles being driven (eighteen inch square or twenty four inch square), the quantity (in this case the department of transportation measures their quantities in how many linear footage, or actual piles that were driven), the unit cost, and the contractor who performed the work.

In order to receive a proper estimate of the overall projects, the researchers will assume that one hundred projects for each of these five items will be sufficient enough to give a realistic estimate of the entire population. Once one hundred projects have been recorded the project identification numbers from all five of the separate categories will be separated and organized numerically.

Once this data has been collected from the website members of the Florida department of transportation will be contacted to determine which projects, that have been extracted for the study, were performed during the day-time, which were performed during the night, and then which of the projects were performed during both the day and the night. Projects that were performed during the day as well as the nighttime are known as “hybrid” projects. When these items have been determined, the data will be separated into the day, night, and hybrid project categories. These projects will be separated and averaged.

Once it has been determined when each of the projects were performed the researchers will have the ability to statistically determine if there is a significant difference in cost between performing these construction processes during the night-time than there is to performing them during the day. From this point the differences in costs level should also reflect the overall difference in productivity between the different times of day.

It is important to mention that this study will be sensitive to the differing cost inflations of construction work over the four year span. Because of this, this study will attempt to “normalize

the data” by using a construction cost index and by bringing the past unit costs into terms of the year 2007.

CHAPTER 4
RESULTS AND ANALYSIS

Introduction

This research project will focus on the differing costs between day and night construction for paving and piling operations. In the end it is hoped that a meaningful difference will be found in the unit prices between performing the construction project during the day-time and by performing the project during the night-time. This answer will aid FDOT in determining the cheapest and most productive way to perform a roadway construction project.

This study focused on five different items within the asphalt paving and pile driving realms. All asphalt paving operations that used a FC-6 Friction Course, a Superpave Traffic C Structural Course, or a Superpave Traffic D Structural Course were open for analysis. In addition, pile driving operations that dealt with eighteen inch prestressed concrete columns and twenty four inch prestressed concrete columns were also open for analysis.

Once it had been determined which items were to be studied, a general sample size had to be decided which would correctly portray the entire population. It was determined that each of the five items would strive for 90-100 separate projects. This amount of projects would give the study a time frame between the years of (2004-2007), and would account for projects all around the state. This sample size would adequately be able to describe the current trends occurring throughout the state of Florida.

FC-6 Friction Course

Introduction

The first item that was researched during the study was the Friction Course FC-6. Over the four year span (2004-2007), this course would become the most popularly used friction course. It was important for the sake of the study to choose the items that were the most

prevalently used throughout the study. By using the most common materials, the study will not only achieve the largest sample size possible, it will also beneficially affect the most future projects. Once all of the data had been pooled and each of the members of the department of transportation had been contacted, it came time to analyze the data and to determine any trends.

While analyzing the data one thing became very apparent. Despite the state of Florida's insistence on using a unit price per ton of asphalt, many of the projects were quantified by the cubic yard method. This presented the study with a severe problem. If the study had two separate units of measurement it became difficult to compare the overall extent of difference, due to the differing of measurement quantities. In order to remedy this, the research concentrated on performing separate analysis for each different sect of values. Despite the lack of uniformity the same trends should still be noticed and analyzed.

Percentage Breakdown of State Projects

Before delving into the differences of prices between day and night constructions, the study felt that it is important to provide the overall breakdown of asphalt paving Friction Course FC-6 projects throughout the state of Florida during this time period (Figure 4-1).

This study shows that through the years of (2004-2007), nearly half of the asphalt paving projects (45%) occurred during the day-time while projects that included day and night-time construction accounted for 38% of the remaining projects. In the end night-time construction only accounted for 17% of the total projects. Once the total costs of these projects have been determined it will be decided the amount of money that could have been saved by the department of transportation throughout this time period by employing differing forms of construction.

Comparison of Differing Construction Methods

The next item of business that needed to be tended to during the analysis period was determining the differences in costs that were associated with day, day & night, and night-time

construction projects. While analyzing the differences in costs it was noticed that there were two different prevailing unit measurements that were recorded by contractors. The usage of unit price per ton and unit price per cubic yard were both used by the FDOT, so both sets of data were analyzed: average unit price per ton (Figure 4-2) and average unit price per cubic yard (Figure 4-3).

While looking at Figures 4-2 and 4-3 it becomes apparent that night-time construction is significantly more expensive than day-time construction. Interestingly enough, if the work were to be performed during the day as well as the night throughout the life of the project, it would be significantly cheaper than either of the two work processes by themselves.

Cost Savings

The last item that was analyzed dealing with Friction Course FC-6 was the potential cost savings that were lost during this time period. Throughout the life of the study there was 164,562.66 tons of asphalt Friction Course FC-6 that were laid throughout the state of Florida. Since it is already known by the study, that performing asphalt paving during the day and night is the most cost effective, the study decided to determine the savings impact that would occur by performing solely hybrid projects (Table 4-1). In order to find this the study multiplied the average price of day and night-time construction times by the total quantity laid during the projects.

This study showed that if projects were performed during the day & night solely through this four year time period, there would have been $3,251,035.91 less spent on roadway construction.

Superpave Traffic C Structural Course

Introduction

The next item that was analyzed during the study was the usage of Superpave Traffic Structural Course. Superpave Traffic C is the most popularly used structural course of asphaltic concrete throughout the state of Florida for the last four years. Because of the extensive usage of this product it becomes increasingly important that the process of paving be as cost effective as possible.

Unlike the Friction Course FC-6, there were many moreprojects that used Superpave Traffic C structural course paving, and since there was a much larger sample size of projects to choose from, all of the projects that the researchers decided to record were recorded in terms of unit price per ton measurements. This allowed for a greater sample size than the other items studied in the project and allowed the researcher the ability to draw stronger conclusions from the research. It should be noted that since there was such a large volume of Traffic C paving it was only necessary to draw data for two separate years.

Percentage Breakdown of State Projects

Much like before, this study began with a percentage breakdown of the working methods of Superpave Traffic C Structural Course throughout the state (Figure 4-4).

This breakdown of projects looks eerily similar to the usage of Friction Course FC-6. Day-time projects accounted for 43% of the total projects and hybrid projects account for 41% of the total projects. Although there is a difference in that projects that use day and night-time construction are slightly more prevalent. The usage of night-time projects is almost identical at 16% of the total projects.

Comparison of Differing Construction Methods

After determining the percentage breakdown of state projects, the next item in the study was to determine the average unit prices of day, day & night, and night construction. Much like before the numbers were analyzed and put into graphical form (Figure 4-5).

This graph shows a remarkable difference to the paving operations that include Friction Course FC-6. The study including Superpave Traffic C instead is predominately less expensive when performing the work during the night-time, rather performing it during the day. Furthermore it is less expensive to perform work during the day and night than it is to solely perform it during the day. In the end it is found that the most expensive form of Superpave Traffic C asphalt paving is to perform the work solely during the day.

Cost Savings

The final step of the analysis of Superpave Traffic C was to determine the effective cost savings that the state of Florida could have witnessed during the last two year time period. This amount will be determined by multiplying the total amount (tons) of asphalt laid throughout the one hundred projects collected. This number will be multiplied by the average cost of the most cost effective time to perform the work. In this case the cheapest time period is during the night. This number will be compared to the total cost that was actually incurred during the 100 projects. Once the numbers have been compared, it will show the potential cost savings (Table 4-2).

By performing this hypothetical study it is noticed that if, in this two year time period if construction had been performed during the night-time there would have been savings of $10,213,454. This is an amazingly high number if you were to take into effect that this was only a two year time period. By performing construction during the most cost effective times, the state of Florida could be saving millions of dollars a year.

Superpave Traffic D Structural Course

Introduction

The third item out of five that was studied on this research project was Superpave Traffic D Structural Course. Superpave Traffic D is the second most popularly used asphalt structural course throughout the state of Florida for the last four years, second only behind Superpave Traffic C. It is the second structural course that will be studied on this project and will conclude the usage of asphalt paving when the data had been analyzed (one friction course and two structural courses). The idea of this study is to continue with our research to determine the most cost effective form of construction and continue to provide an aid to the state of Florida on cost related issues.

Since Superpave Traffic D is the second most popular structural course used, there are far less projects to draw from. Therefore many of our projects suffer the ill fate that the Friction Course FC-6 projects suffered, many of the projects have differing unit price measurements. In this case the data will be divided into two separate measurements, unit price per ton and unit price per metric ton.

Percentage Breakdown of State Projects

Continuing with the earlier trend set by the analysis, the study will dissect the data in order to determine the current percentage breakdown of differing forms of construction (Figure 4-6).

Looking at the pie chart, it is noticeable that Superpave Traffic D asphalt paving performs a greater deal of its paving operations during the day & night than its counterparts. Nearly 50% of the time Superpave Traffic D projects are performed during the day and the night. It is also noted that this is the lowest percentage amount of solely day-time construction projects of either of the two asphalt paving procedures studied. It is also interesting to note that despite

the drastic change in percentage between day-time construction and day and night construction, solely night-time construction has stayed remarkably exactly the same, in between the 15%-20% area. For some odd reason it seems that projects that are performed with Superpave Traffic D are far more progressive than ones that are performed with Superpave Traffic C.

Comparison of Differing Construction Methods

Continuing in the familiar path of the study, Superpave Traffic D was analyzed in order to determine which the most cost effective form of construction is. By computing the average unit price per ton for each form of construction (day, day & night, and night) it can be determined which form of construction should be the most used. The following breakdown of numbers were broken down and then put into graphical form in average unit price per ton (Figure 4-7) and average unit price per metric ton (Figure 4-8).

After taking time to analyze the data, one might realize a few noticeable trends. First of all, much like the data shown in Figure 4-5, involving Superpave Traffic C, it shows a remarkable difference. But unlike the Superpave Traffic C where day-time construction is the most expensive form of construction, Superpave Traffic D has day & night construction as the most expensive form of construction. It is also important to realize that the numbers associated with unit price per ton and unit price per metric ton are very consistent with one another, so it can be assumed that the current conclusions are correct.

It is interesting to note that while dealing with structural course paving projects night-time construction is the most cost effective measure. And while dealing with Friction Course FC-6 paving projects working during the day and during the night is the most cost effective form of construction.

Cost Savings

Just like the other items discussed in the study, the next step in the analysis portion of the study is to determine the cost savings that the project would incur if they were to be completed using the most cost effective form of construction. In this specific instance the most cost effective form of construction for Superpave Traffic D asphalt paving would to perform the project during the night-time.

First, in order to determine differences in price it is important to determine the total quantity of Superpave Traffic D that is in the study. Once the total quantity of asphalt had been determined the study decided to multiply the average unit price of the cheapest form of construction (night) times the total quantity of Superpave Traffic D. Once the hypothetical cost of night-time projects has been determined it can be subtracted from the total cost of the 100 sampled projects to determine the cost savings that night-time construction will create (Table 4-3).

After looking at Table 4-3 it can be seen that if construction projects dealing with Superpave Traffic D had been paved during the night for the years 2004-2007, the state of Florida would have saved nearly 5 million dollars.

Prestressed Concrete Pilings

Introduction

The fourth and fifth items that were analyzed during this study were the pile driving procedures associated with eighteen inch and twenty four inch prestressed concrete pilings. Eighteen inch prestressed concrete columns are the most common form of concrete piling used throughout the state of Florida for the last four years. Twenty four inch prestressed concrete pilings being the second most popular piling used. Despite it being the most common forms of pilings, there still were the most difficult items to get information on throughout the study. In

entirety, the project ended with 91 viable projects that contained eighteen inch or twenty four inch prestressed concrete piles.

Not only was the eighteen inch pile, as well as the twenty four inch pile (mentioned in the next section), the most difficult items to attain information on. But the greater majorities of information on the subjects were differing unit measures. For example all of Superpave Traffic C projects were measured in unit price per ton. The Prestressed Concrete Pilings were measured by square footage, linear footage, and by each pile driven. Because of this, it was a little difficult to achieve significant amount of data per measurement type in order to see specific trends.

Percentage Breakdown of State Projects

The first thing that was studied throughout the project was the percentage breakdown of day, day and night, and night-time pile driving projects (Figure 4-9). With this information it would become apparent the general tendencies of the state of Florida towards pile driving procedures.

After looking at Figure 4-9, it becomes apparent that it is not common practice to perform pile driving activities during the night-time alone. Interestingly enough the only pile driving projects that were performed during the night over this four year span, were performed in district 6 (Miami). But for the most part, the pie chart suggests that the majority of projects are preferred to be performed during the day alone or sometimes perform pile driving in a day and night method.

Comparison of Differing Construction Methods

Eighteen inch prestressed concrete piling

The next step in the research study was to analyze the data and to determine the differences in costs associated with the different times of the day. The following data was analyzed and sorted into different graphs, that included the different sizes of piles (eighteen inch)

as well as the different unit price measurement, linear foot, and each pile. The following two figures, Figure 4-10 and Figure 4-11 dealt with eighteen inch prestressed concrete piles that were measured in linear footage and per pile respectively.

The previous two figures show that despite the rare usage of night-time pile driving procedures, they in essence have been the most cost effective. It becomes relatively difficult to determine if the night-time projects are as effective as they seem in these graphs however, because there is a very small sample sizing of pile driving.

Twenty four inch prestressed concrete piling

The twenty four inch prestressed concrete piles were also analyzed in a linear foot, each pile manner, much like the eighteen inch piles were before. These items were analyzed in order to determine whether any significant differences could be found. The graphs representing the unit price per linear foot (Figure 4-12) and the unit price per pile (Figure 4-13).

Much like before in the analysis performed on the eighteen inch prestressed concrete piles; night-time construction provides a much more cost effective solution to pile driving activities. However there is a problem with this conclusion. There is not enough data in the area to fully conclude that night-time pile driving procedures are the more cost effective option. For the benefit of the study we will assume that the data above is correct. And we will assume the unit costs are indicative of the population.

Cost Saving Eighteen Inch Prestressed Piles

The last item of the study will conclude with the cost savings that can be seen with more cost effective forms of construction. In this instance, the most cost effective form of construction for eighteen inch prestressed piles would be to perform the project during the night-time. It should be noted that this is a purely hypothetical analysis due to the fact that there is a very small sample size of night-time construction. Since the sample size is so small, it could not be

determined if the average unit price of night-time pile driving is a good indicator of the population's behavior or not.

First, in order to determine differences in price it is important to determine the total linear footage of eighteen inch prestressed piles that were driven. Once the total linear footage had been determined, the study decided to multiply the average unit price of the cheapest form of construction (night) times the total linear footage that had been driven over the four year period. Once the hypothetical cost of night-time projects has been determined it can be subtracted from the total cost of the 90 sampled projects to determine the cost savings that night-time construction will create (Table 4-4).

After looking at Table 4-4 it can be seen that if construction projects dealing with eighteen inch prestressed piles had been driven during the night for the years 2004-2007, the state of Florida would have saved $1,248,637.97.

Cost Saving Twenty Four Inch Prestressed Piles

As seen with asphalt paving and eighteen inch prestressed pile driving, the study set out to find the hypothetical costs savings that could be seen by performing the most cost effective form of construction. In this specific instance the most cost effective form of construction for twenty four inch prestressed pile driving would be to perform the project during the night-time.

First, to determine differences in price it is important to determine the total linear footage of piles that were driven in this study. Once the total linear footage had been determined the study decided to multiply the average unit price of the cheapest form of construction (night) times the total linear footage, to determine how much would be spent if all of the twenty four inch piles that were driven, were performed at night. Once the hypothetical cost of night-time projects has been determined it can be subtracted from the total cost of the 100 sampled projects to determine the cost savings that night-time construction will create (Table 4-5).

Table 4-5 shows that if construction projects dealing with twenty four inch Prestressed Piles had been driven during the night for the years 2004-2007, the state of Florida would have saved $1,447,282.30.

Economies of Scale

Varying average quantities of projects were used during our study. There can be a materially difference of unit costs that are bid on projects that have large amounts of work to be done in comparison to a small amount of work to be done. This data could possibly skew the findings of this study and it is important to point out this fact before hand. In Table 4-6 there is data for each individual item of construction that was studied throughout this project, as well as the average quantities and average unit prices for all of the projects. These numbers will be compared to one another to determine if there were any significant differences that can be seen.

Table 4-6 is set up to determine if there are any material differences that can be attributed to economies of scale. Economies of scale can be a rather difficult thing to determine, but what this study decided to do, was to divide the average quantities by the average unit prices. By doing this, it gives the research a base point for determining how much the quantity size played in the pricing for each item. In these cases, the higher the ratio means, the more likely economies of scale are present.

The first item that is present on Table 4-6 is Friction Course FC-6. While looking at these numbers it appears that economies of scale could have affected the rather low average unit cost that is associated with day & night construction. Its ratio number is twice as high as the other two times of construction, it has by far the largest average quantity per project, and it is also the most cost effective form of construction. These numbers could possibly be influenced by economies of scale.

The second item that was analyzed was Superpave Traffic C. This graph suggests that economies of scale did not affect the average unit costs of construction. In fact the most cost effective form of construction was the type that had the lowest average quantity per project and also it had the lowest ratio as well. This suggests that economies of scale had little to do with influencing the average unit cost for night-time construction.

The third item that was analyzed was Superpave Traffic D. Much like Superpave Traffic D, the graph suggested that night-time construction data was not influenced by economies of scale. In fact night-time construction had the lowest average quantity, the lowest average unit price, and the lowest average ratio for all forms of construction.

The last two items that were studied were the eighteen inch prestressed pile and the twenty four inch prestressed piles. The eighteen inch prestressed piles followed in the Superpave structural course asphalt paling's footsteps and showed no sign of economies of scale. Much like before with the structural paving studies, eighteen inch prestressed piles had the lowest average quantities per project, the lowest average prices, and the lowest ratio.

It became difficult to determine if there was a significant difference of costs that could be attributed to economies of scale for twenty four inch prestressed piles however. The most cost effective form of construction had by far the highest ratio, but its average quantity per project was strikingly similar to the different times of construction. Because of this, it is unlikely that economies of scale played a large difference in the average unit costs of the projects.

Table 4-1. Friction Course FC-6 savings during the day and night

	Total Quantity	Average Price	Total Quantity * Average Price
Total Cost			$15,820,520.00
Day & Night	164,562.66	$76.38	$12,569,484.09
Savings			$3,251,035.91

Table 4-2. Superpave Traffic C savings during the night

	Total quantity	Average price	Total quantity * average price
Total cost			$106,080,670.78
Night	1,038,873.17	92.28	$95,867,216.13
Night savings			$10,213,454.65

Table 4-3. Superpave Traffic D savings during the night

	Total quantity	Average price	Total quantity * average price
Total cost			$65,304,654.45
Night	659,821.26	$91.90	$60,637,982.35
Night savings			$4,666,672.10

Table 4-4. Eighteen inch prestressed piles savings during the night

	Total Quantity	Average Price	Total Quantity * Average Price
Total Cost			$19,404,352.67
Night	184,547.50	$98.38	$18,155,714.70
Night Savings			$1,248,637.97

Table 4-5. Twenty four inch prestressed piles savings during the night

	Total Quantity	Average Price	Total Quantity * Average Price
Total Cost			$2,197,834.21
Night	60,330.00	$12.44	$750,551.90
Night Savings			$1,447,282.30

Table 4-6. Economies of scale

	Day	Day & Night	Night
Friction Course FC-6 Average Quantities	46,335.36	73,843.90	44,383.40
Friction Course FC-6 Average Unit Prices	$107.75	$77.61	$120.58
Ratio Ton per Dollar	430.02	951.50	368.08
Superpave Traffic C Average Quantities	370,647.52	447,889.15	220,336.50
Superpave Traffic C Average Unit Prices	$106.11	$105.50	$93.33

Table 4-6 (Cont)

	Day	Day & Night	Night
Ratio Ton per Dollar	3493.07	4245.59	2360.89
Superpave Traffic D Average Quantities	211,113.56	267,380.10	181,327.60
Superpave Traffic D Average Unit Prices	$102.81	$110.74	$97.64
Ratio Ton per Dollar	2053.51	2414.41	1857.13
Eighteen Inch Prestressed Piles Average Quantity	60,887.00	117,671.50	5,989.00
Eighteen Inch Prestressed Piles Average Unit Price	$110.45	$102.74	$98.38
Ratio Linear Foot Per Dollar	551.25	1145.29	60.88
Twenty Four Inch Prestressed Piles Average Quantity	20,541.00	19,656.00	20,133.00
Twenty Four Inch Prestressed Piles Average Unit Price	$50.66	$46.33	$12.44
Ratio Linear Foot Per Dollar	405.50	424.25	1618.31

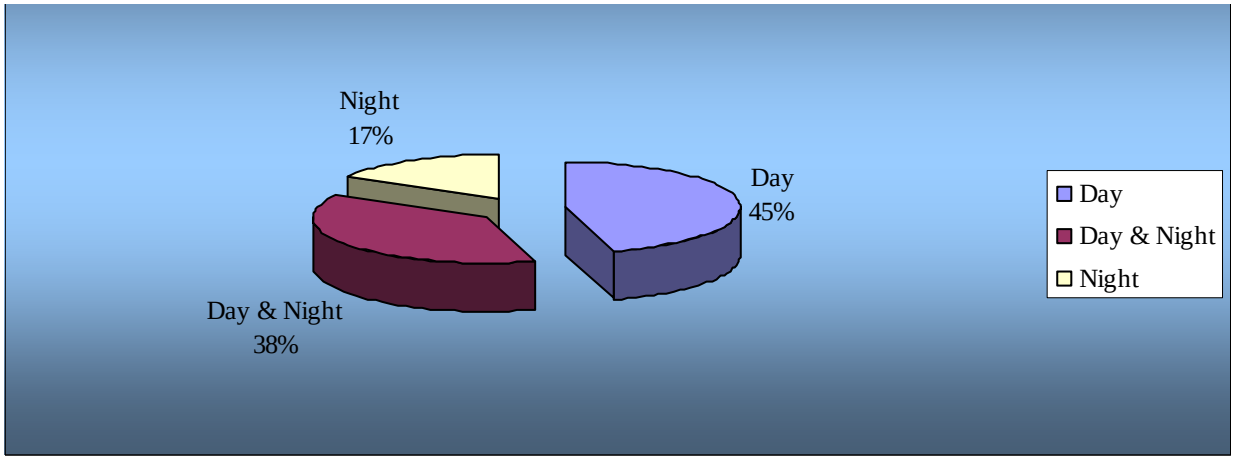

Figure 4-1. Percentage of Asphalt Friction Course FC-6 paving projects (2004-2007)

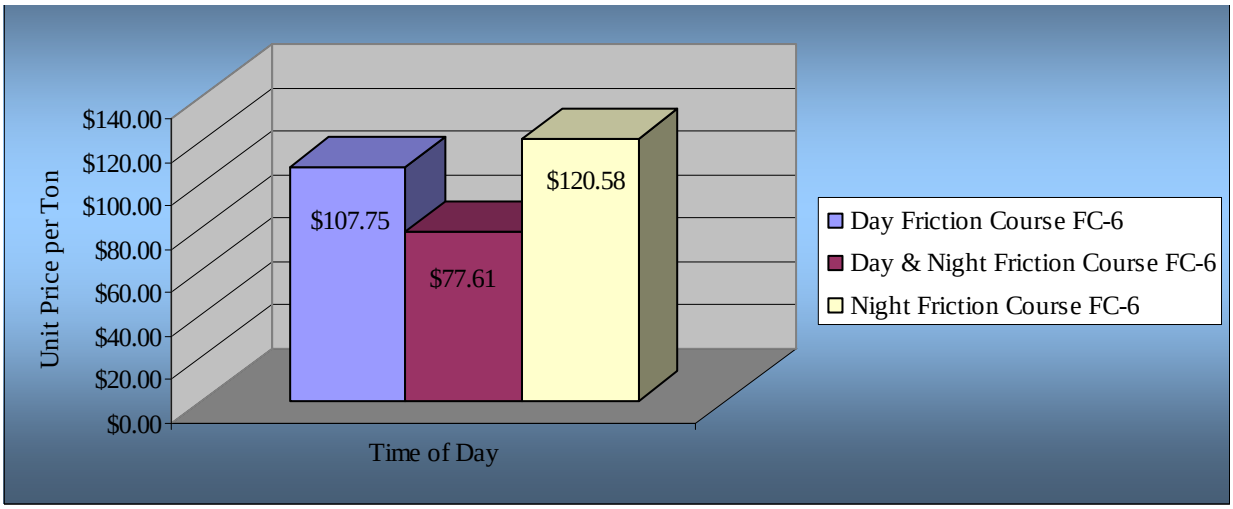

Figure 4-2. Asphalt Friction Course FC-6 price per ton

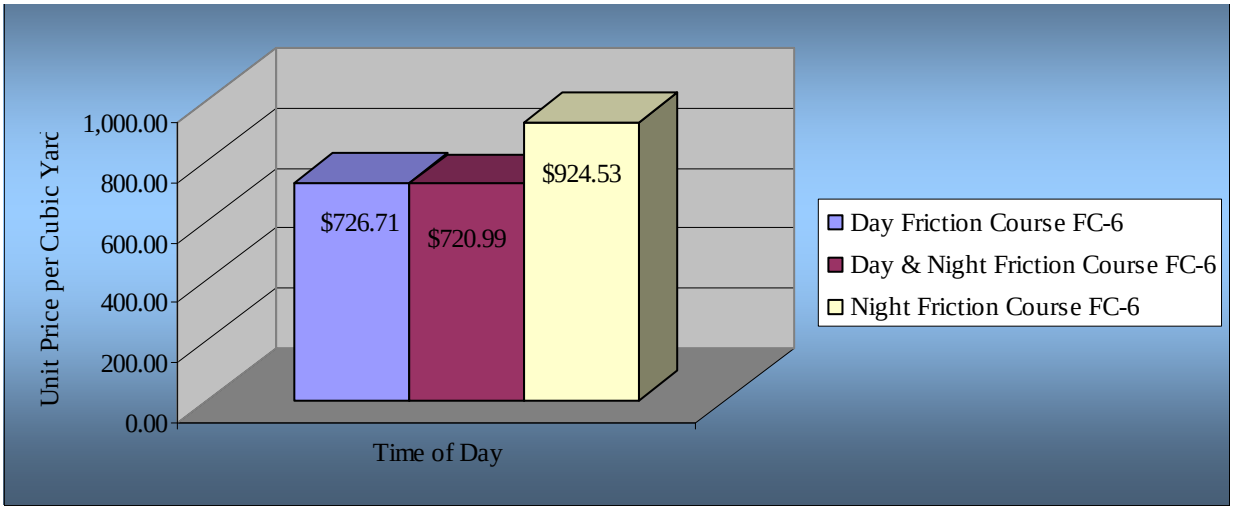

Figure 4-3. Asphalt Friction Course FC-6 price per cubic yard

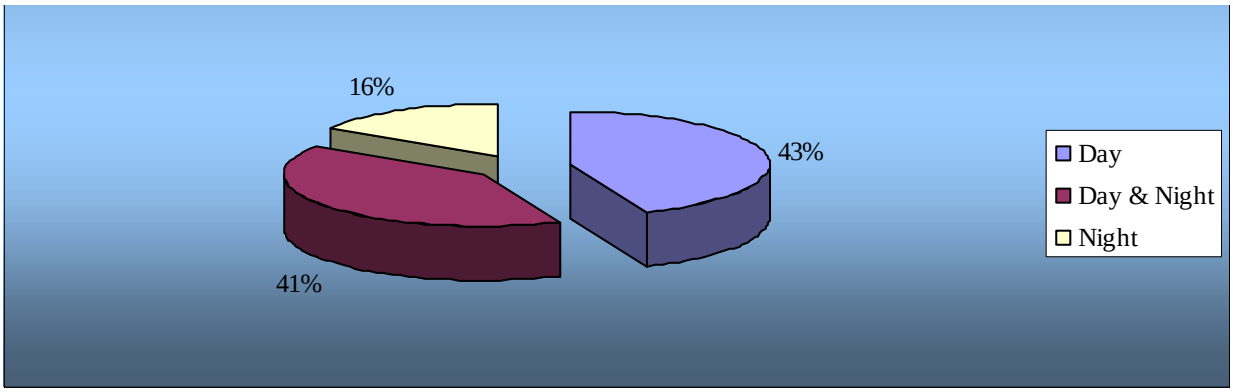

Figure 4-4. Percentage of Superpave Traffic C paving projects (2006-2007)

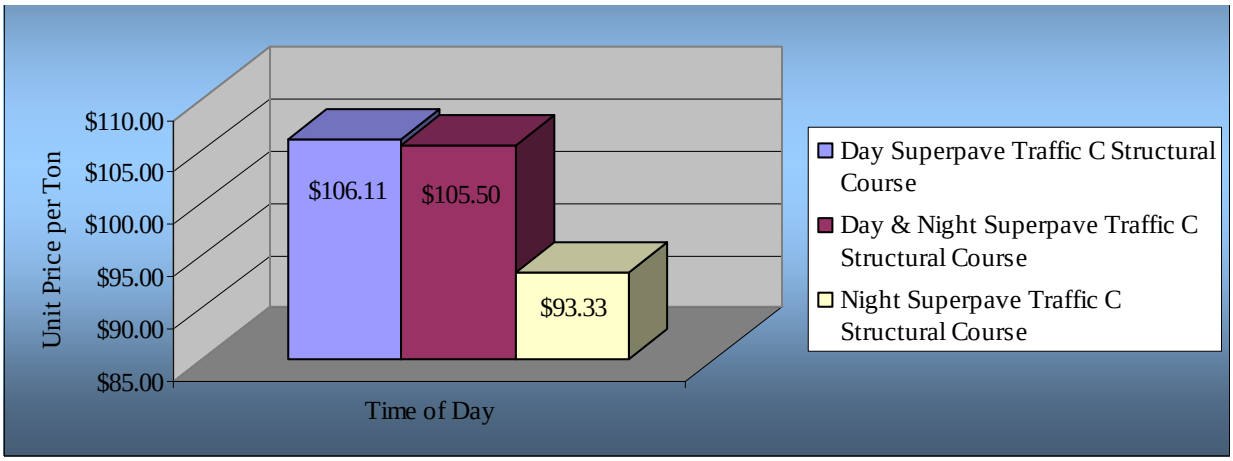

Figure 4-5. Superpave Traffic C price per ton

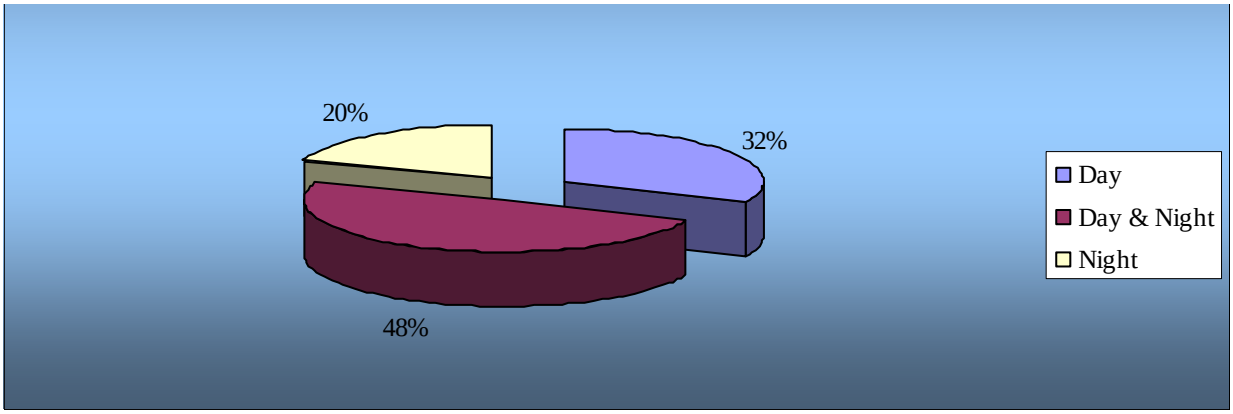

Figure 4-6. Percentage of Superpave Traffic D Structural Course paving projects (2004-2007)

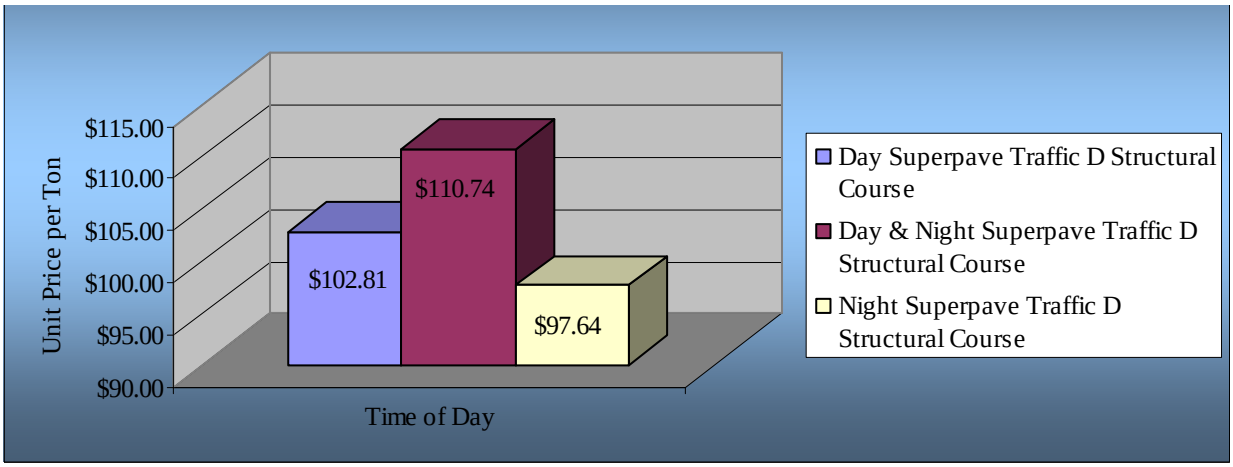

Figure 4-7. Superpave Traffic D Structural Course price per ton

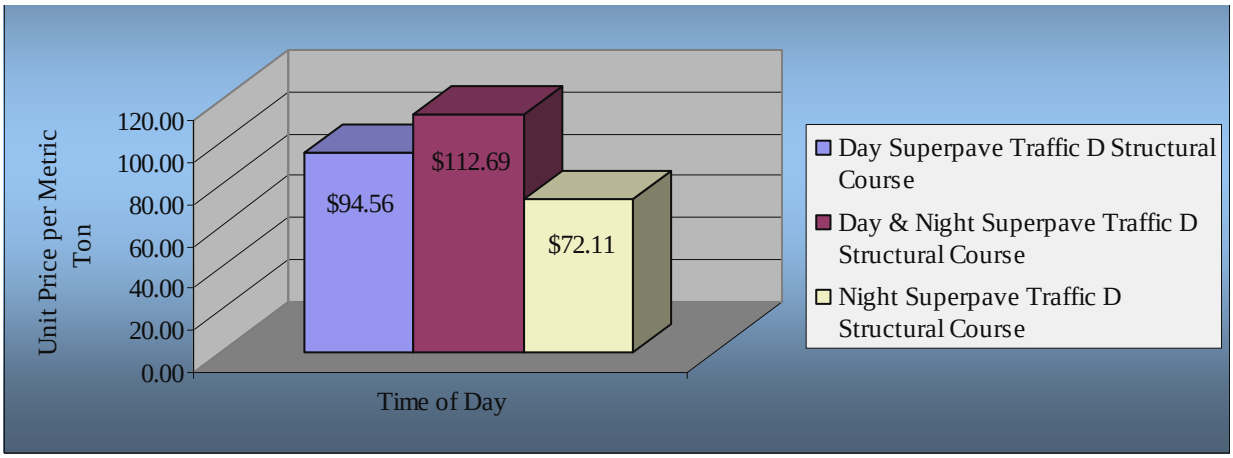

Figure 4-8. Superpave Traffic D Structural Course price per metric ton

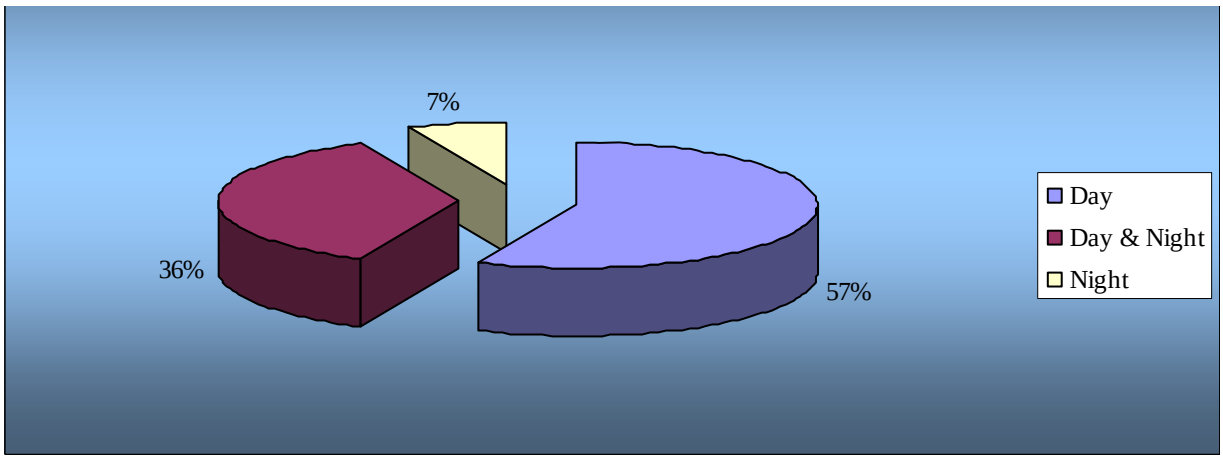

Figure 4-9. Percentage of concrete piling projects (2004-2007)

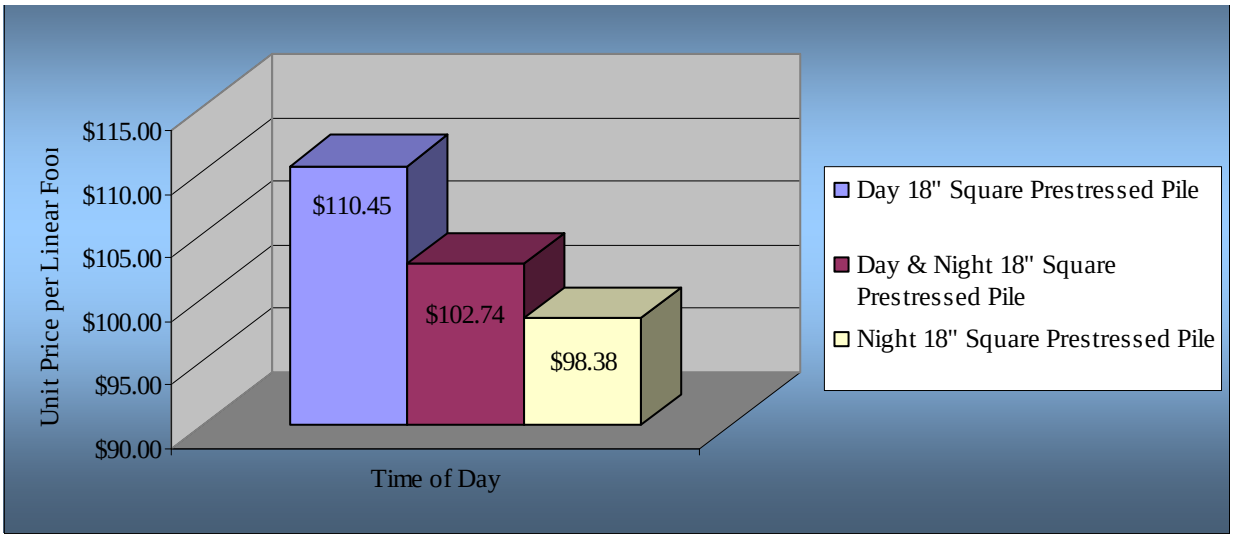

Figure 4-10. Eighteen inch prestressed pile prices per linear foot

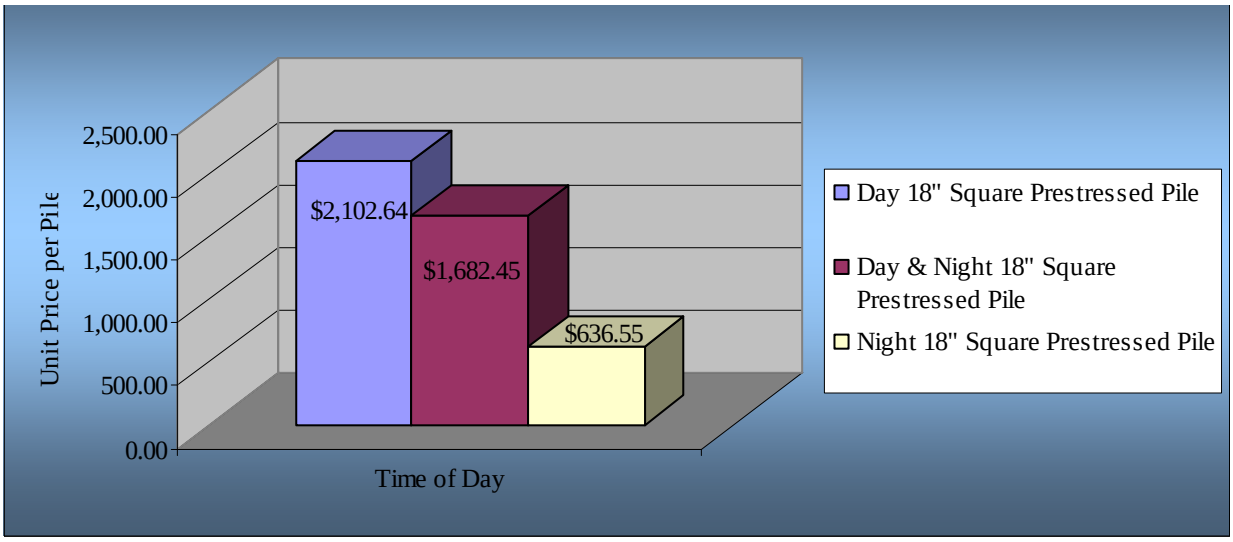

Figure 4-11. Eighteen inch prestressed pile prices each

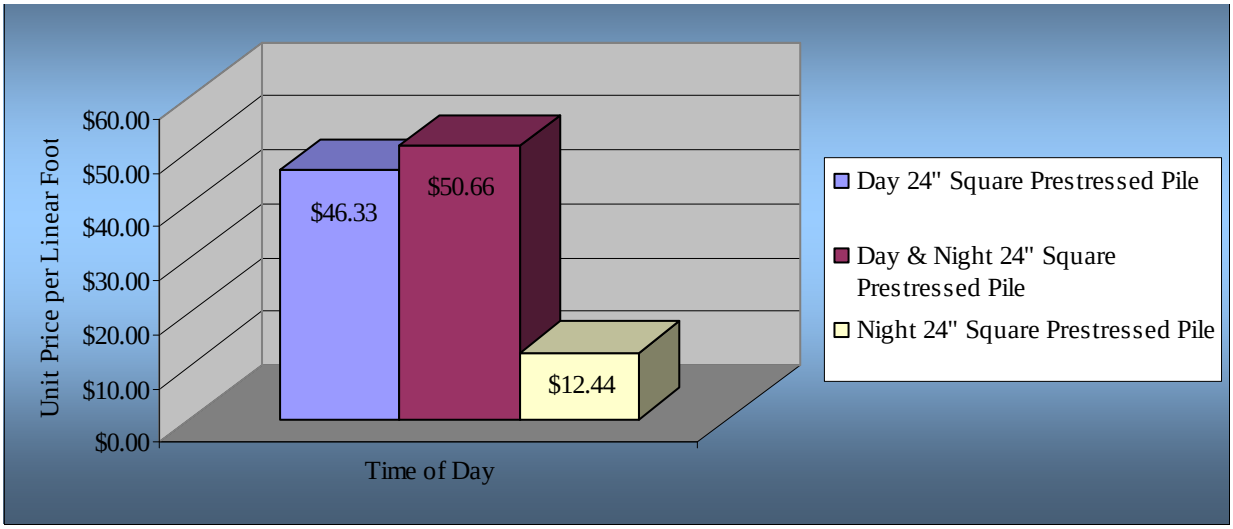

Figure 4-12. Twenty four inch prestressed pile prices per linear foot

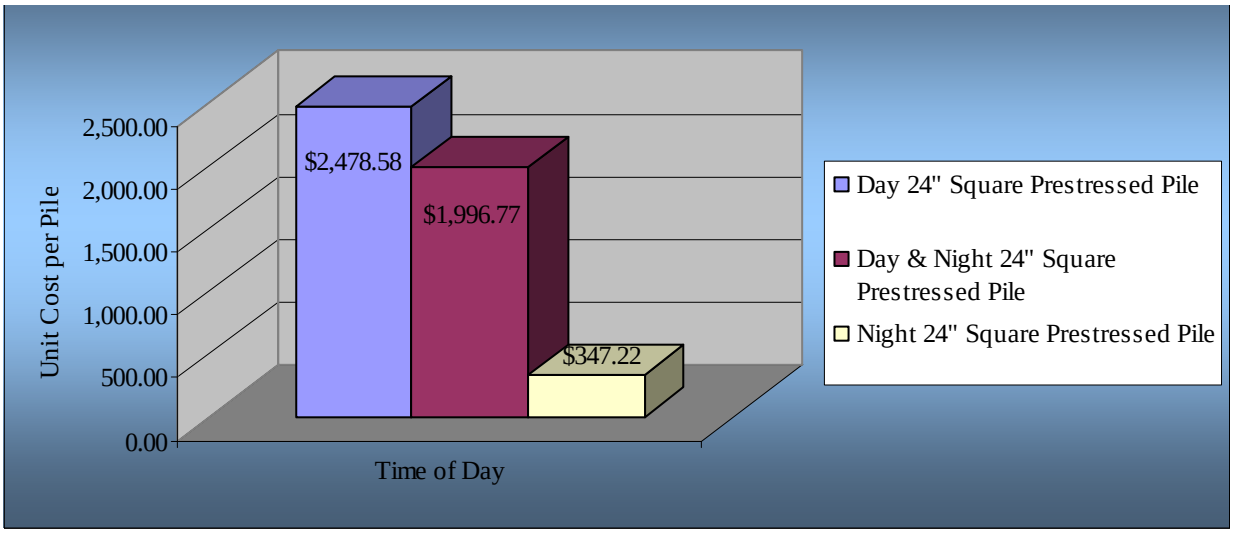

Figure 4-13. Twenty four inch prestressed pile prices each

CHAPTER 5
CONCLUSION

Introduction

Night-time construction has been a hot bed for debate. Many critics decide that night-time construction is necessary due to the reduction in traffic volume. Others argue that night work construction is simply too dangerous to perform. The debate still wages on to this day. So far although many of the studies have been performed on night-time construction have been performed on the safety impacts that night construction brings to the work environment, or what kind of lighting is adequate in the work place.

This project strayed from that blue print. Instead this study focused on the cost impact that night-time construction has on a job site. The reasoning behind concentrating on the cost impact of construction was actually very simple, since a night-time construction work zone area has been considered by many studies to be far more dangerous than while working during the day; it becomes very important to rationalize why night-time construction is performed at all. The thought process is that by proving some items are more productive while being performed during the night, this would give the Florida department of transportation reason enough to continue regulating traffic control and perform the work during the night-time.

From the beginning, this study was performed to see if there was some sort of material difference between the costs associated with day and night-time construction. The study was constructed on the fact that the unit cost data would be compared and contrasted to each individual type of construction to determine which item is truly the most cost effective. This study focused on finding the most cost effective form of construction and then providing a material baseline that could be followed for future projects.

This study concentrated on five main items of roadway construction. These five items included asphalt Friction Course FC-6 paving, asphalt Superpave Traffic C Structural Course paving, asphalt Superpave Traffic D Structural Course paving, eighteen inch prestressed concrete pile driving, and twenty four inch prestressed concrete pile driving. These items were the most prevalently used materials in asphalt paving and pile driving. It was felt by the researcher that these five items would have been used often enough in order to reach a significant conclusion of pricing differences.

Friction Course FC-6

The first item that was analyzed during the study was the asphalt Friction Course FC-6. This friction course was the prevalently used material while dealing with friction course paving.

This study showed that the most cost efficient projects were the ones where construction was performed during the night and during the day. Conversely the study showed that the least cost efficient projects were the ones where the construction was performed solely during the night-time. Hopefully the trends will shift and hybrid construction will be performed more often while dealing with friction paving.

Further along in the study a hypothetical situation was set up. This situation was set in place to prove the excessive amount of money that had been spent on other forms of construction through out the time period. In this, the total amount of money spent on Friction Course FC-6 paving for all three types of projects were compared to what the cost would have been by performing the cheapest form of construction. In this case the cheapest form of construction would be by performing construction during the day and during the night. If all 100 projects that were analyzed had been hybrid projects (performed during the day and night), than the department of transportation would have saved $3,302,576.44, over the four year period.

Superpave Traffic C Structural Course

The second item of the study was the Superpave Traffic C Structural Course. This course is the most popularly structural course used by the FDOT over the four year time span of 2004-2007.

By continuing in the tracks of the Friction Course FC-6 study, the specific projects were collected and analyzed to determine if there was a significant difference of cost. In the end it turned out that the least expensive form of construction was diametrically opposite of Friction Course FC-6 projects. Instead projects that were performed during the night-time happened to be far less expensive to those that were performed during the day-time. In fact day-time construction was the most expensive form of Superpave Traffic C Asphalt Paving.

To continue with the study another hypothetical situation was constructed in order to determine that amount of money that could have been saved by the department of transportation if all Superpave Traffic C paving operations were performed during the night. The study showed that over the two year time span of projects there could have been savings of $10,187,276.58.

Superpave Traffic D Structural Course

The last paving operation that was included in the study was the Superpave Traffic D Structural Course. Superpave Traffic D is the second leading material used on structural course paving operations, behind Superpave Traffic C.

After analyzing the project data it was determined that the results almost entirely mirrored those of Superpave Traffic C. This should come as no surprise because they are both structural courses that use the same kind of application. The lone difference in this study was the fact that day and night construction was the most expensive form of construction for Superpave D construction projects. Night-time operations were the cheapest form of construction and day-time work was considered the second least expensive.

In order to determine the potential impact that scheduling had on the total cost of construction another hypothetical study was constructed. Much like before the least expensive construction process, night-time construction was compared to the overall amount of money that was spent on the 100 projects in question. Once the numbers had been analyzed it was determined that there could have been possible savings $4,594,931.94 over the last four year span.

Pile Driving

The last item that was studied was the usage of eighteen inch and twenty four inch prestressed concrete pilings. These two sets of pilings were also the most popularly used over the four year time span.

Once the data had been separated and analyzed it was determined that the data was in such disarray that there was not a significant difference that could be noted. This is because there were only 91 total projects over a four year time period that could be recorded. Furthermore these 91 projects that were recorded had two different unit price measurements to draw from (linear foot and each pile). Because of this the data that was found was skewed and could not be determined.

If a conclusion had to be derived from the data given, it would be that there is a significant cost savings that are associated with performing night-time construction. In all there could possibly had been savings, for eighteen inch and twenty four inch piles, of $1,248,637.97 and 1,447,282.30 respectively. But as was stated earlier, there is such a shortage of night-time projects, that it can not be assumed that the data that was recorded can truly be indicative of the population.

Recap

The hypothetical study was constructed in order to show the full amount of savings that the department of transportation could be witnessing each year due to employing more night-time work projects. After adding up the savings this study showed that the state of Florida could have saved $20,780,705.23, from 2004-2007, by using the more cost effective measures. This near 21 million dollars only includes two years worth of Superpave Traffic C asphalt paving as well, so the amount of savings may in fact be much higher than this if all fours years of Traffic C were taken into account.

It seemed that the department of transportation needed a reason to continue performing night-time construction. Projects were more dangerous than during the day and illumination requirements were bothersome. There needed to be a reason other than traffic control in order to rationalize performing construction during the night. Now it can be argued that night-time construction is a far more cost effective process than work during the day for some items of work.

This proves that FDOT is better off performing night-time construction on projects that deal with asphalt structural course paving. Conversely, it is in the Department of Transportations best interest to perform friction course paving during the day as well as during the night. By focusing on producing projects more during these time periods the department of transportation would be saving millions of dollars annually.

CHAPTER 6
RECOMMENDATIONS

Introduction

Currently much of the research that has been performed in the way of night-time construction have focused on the safety impacts that night-time work zones create. Everything from reaction time, to illumination standards, to crash rate data has been looked at and analyzed to determine the safest and most effective work zone area. The dangerous increase in work zone related accidents should continue to be studied and analyzed to determine whether having night-time construction is feasible or not.

If I were to give recommendations for certain research projects that took into account night-time construction I would personally rather see topics stray from the common one (safety). I would focus more on profitability and productivity differences that night-time situations create. Since it has been strongly suggested and accepted that night-time construction creates an atmosphere that is more dangerous to drivers on the road and to the worker in the construction area, it should at least be proven to provide the contractor and the public with some economic benefits. These benefits should at least out weigh the significant safety strain that night-time construction creates.

Research is needed regarding night-time construction. These ideas serve as a stepping stone to other research ideas that will hopefully improve the application of night-time construction or prove that night-time construction is an expendable item that produces more bad outcomes than it does good outcomes.

Day vs. Night Productivity

The first study that will be recommended will be to determine the difference in productivity between day-time and night-time constructions. Many people have argued that

night-time construction is more productive because construction crews work in more manageable weather conditions, work in more spacious areas, and do not have to worry about traffic being as large of a factor. Conversely other experts argue that since the night zone work area is not as well lit as it is during the day, than construction project productivity will actually be lower than the day.

It would be a very beneficial study to help prove whether night-time construction is more productive or if it is less productive. Even though this would be a very beneficial study for the department of transportation to conduct it will also be a very difficult study to quantify. This would be because no two construction sites and projects are the same. There will always be external factors that will get in the way of the data that needs to be recorded. In addition to this, it will also be very hard to quantify productivity rates while there are many different construction crews performing construction projects for the state.

In my mind there would only be one way to perform this study. First, it would be important to concentrate on a single construction crew. This way the study can compare “apples to apples”, meaning that it is easier to compare a construction crew against itself than it would be to compare it against a separate construction crew. By comparing one crew to another, it will provide inherent flaws to the study. What if one of the crews is more productive naturally than another? What if one crew takes a longer time to produce the work but produces a higher quality project? These items will poke holes into the study. So first it will be important to concentrate on one construction crew. This crew should be of decent size and should be one of the more popular construction crews in the state. This will allows the research to draw from a number of different projects.

Secondly only a number of construction processes should be studied during this study. By concentrating solely on asphalt paving, the researcher will be able to determine the amount of time the asphalt paving crew took to lay down a certain tonnage of asphalt. This will allow the researcher to receive obtainable information, instead of going on a wild goose chase and breaking down the thousand of construction processes that happen on each and every construction site.

State of Florida Cost Analysis

The second research project that will be suggested is one that will be very similar to the research project that I presently just finished. This project will focus on the different unit cost for specific districts throughout the state of Florida. A number of well defined construction processes that are common every day items, such as paving, will be studied and analyzed towards finding average unit prices.

Once it is determined what the average unit prices are for specific items of work, the data will be further broken down into individual work districts. The same analysis will take place and it will be determined what districts are paying for specific types of work to be completed.

The rational behind this study is to look at the state of Florida as a whole and determine where the unnecessary unproductive cost is coming from and eradicating it. If for some reason the study finds that one district is spending much more on average for an item of work than another item, this will allow the department of transportation the ability to conduct their own studies to determine what is happening and why it is happening.

Crash Test Data

The final research suggestion that I recommend, will follow in the long line of past research projects. This project will concentrate on the safety impact that night-time construction has on the traveling public. The difference that this research will have on the past projects is that

it will not focus on the factors that create work zone crashes, nor it will focus on the ways to prevent crashes in the first place. Instead this project will focus on the different times of accidents that occur near work zone areas.

This study will concentrate on the crash data that the department of transportation has regarding work zone accidents. Once it has been determined the amount of crashes that have occurred in areas where there are active night work zones it will be analyzed to determine at what times these accidents occurred. Once these times have been analyzed it will allow the researcher to develop his or her own hypothesis as to why this time period is statistically more dangerous in comparison to other time periods.

In the end the researcher will either determine the problems that produce more crashes and develop a process that will aid in preventing crashes during this time period. Or it will allow the researcher to develop a construction plan that will perform less work during these time periods so as to reduce the amounts of crashes that are present throughout work zone areas.

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BIOGRAPHICAL SKETCH

Steven Brent Thurn was born in 1984 in Houston, Texas. Some four years later, he and his family moved to Vero Beach, Florida. He attended high school there at Saint Edwards School. Once he graduated high school he attended the University of Florida, where he was awarded the Bachelors of Science in Finance in December 2006. In December 2008 he was awarded the Master of Science in Building Construction.