FINAL REPORT

Principal Investigator: Dr. Ralph Ellis, P.E., Ph.D.
FDOT Program Manager: Darryll Dockstader

Development of Procedures for Estimating the Economic Benefits of FDOT Research Project Results

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Department of Civil and Coastal Engineering
University of Florida
(352) 392-9537
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16. Abstract

This is a report on the development of procedures for estimating the economic benefits of Florida Department of Transportation (FDOT) research that was performed, including detailed step-by-step evaluation methods. Case studies were carried out on 20 representative research projects including an assessment of benefits. Observations were made concerning the types of benefits produced by research projects from different functional areas with the FDOT. Included in this report is an inventory of cost and other program data applicable to economic benefit calculations.

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Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction and Research Approach

Introduction

The Florida Department of Transportation (FDOT) supports a comprehensive research program by including research in a wide range of functional areas within the department's operational mission. The FDOT currently recognizes the following functional areas with regard to research operations:

Construction	**Planning**
Environmental Management	**Public Transportation**
Geotech	**Roadway Design**
ITS	**Safety**
Maintenance	**State Materials**
Motor Carrier Compliance	**Structures**
Operations	**Traffic Operations**

Furthermore, the FDOT recognizes the value of measuring both the benefits and the costs of research efforts. FDOT research has greatly benefited state and national transportation systems. The products of research have assisted the FDOT in providing a safe and efficient transportation system and research results have been implemented in all functional areas within the FDOT. The FDOT is undoubtedly a more efficient and effective organization because of its investment in research.

A recent study has developed a suggested process for measuring both the economic and qualitative benefits of research (1). However, a major obstacle in quantifying economic benefits is that FDOT personnel and researchers do not have the tools necessary for estimating future economic benefits.

The first objective of this research is to develop a toolbox of methods for estimating the future economic benefits of research results. More specifically, a key objective of this study is to identify and evaluate the information resources available within the FDOT that can be used to assist in the assessment of research benefits. Given the diverse nature of the research program, a single estimating method will not work for all research products. For example, determining the cost benefits from changes in traffic operations is significantly different from determining the cost benefits associated with materials engineering. FDOT needs a package of economic savings estimating methods that can reliably quantify the future economic benefits of research results. These estimating methods should be simple and straightforward, while providing an appropriate level of precision. They must also be supported by access to cost data and future program planning information. This economic benefit quantification package is designed to serve as a resource for FDOT personnel and researchers. Additionally, the quantification methods will provide the foundation for the development of training initiatives.

The second objective of this research is to develop a series of case studies of FDOT research projects. Each case study will represent a comprehensive report on the research activity, results, and benefits obtained. Both economic and qualitative benefits should be assessed. The future economic benefits of the research results will be estimated using the methods developed in this study. The case studies provide "how to" examples of the estimating process and will support and reinforce the research assessment toolbox. Additionally, the case studies will serve to report on individual project benefits and to demonstrate the value of assessing the benefits of research.

Research Approach

Development of Quantitative Assessment Tools

Investigating the best practices for measuring the economic benefits of research begins with recognizing that not all research projects offer direct economic benefits. Many studies provide valuable non-economic benefits. It is therefore a mistake to try to force an economic benefit assessment on projects that are focused on providing other types of benefits. However, for those projects that do offer a potential economic benefit, it is important to employ standard and credible benefit calculation methods.

Normally, economic benefits are only achieved when something changes as a result of the research effort. Therefore, estimating economic benefits requires identifying what will change and determining the economic effects of the change. The approach adopted in this development effort provides a general step-by-step method with sufficient flexibility to adapt to the many different research topics within the program. A variety of practical examples are provided. Thus, this section was developed to be published separately as a practice guide for researchers and research coordinators.

Developing Case Studies

By consulting with the FDOT Research Center, the current research projects were selected for case study development. An effort was made to include representative projects from each FDOT functional area. The focus was on developing the project "story" in summary format. For consistency, a standard format was adopted.

Project information was obtained from available project documentation including: Original Proposals, Progress Reports, Final Reports, and Summaries. When possible, researchers were also contacted to obtain additional input and insight into the project details.

The case studies provide a useful overview of the range of different research efforts within the FDOT research program. Additionally, the case studies clearly illustrate many of the challenges associated with assessing research benefits.

Chapter 2: Development of Case Studies

Objectives

The case studies serve as a tool for showcasing research program activities. It is important that both external and internal stakeholders are informed about the range of research conducted by the FDOT and the potential benefits of that research. The case studies provide an effective way to tell the research story.

Preparing the case studies also serves to examine the different research activities, and interacting with the researchers provides valuable insight into issues related to assessing research benefits.

Selection of Projects

A preliminary list of research projects was developed jointly by the research team and the FDOT Research Center. Project selection criteria included the following considerations:

- Desire for representation from all functional areas
- Project planned completion dates occuring within the study period of this project
- Funded projects that are not research activities were excluded for example planning projects and technology transfer

Table 1 provides the original project listing. Figure 1 provides a breakdown of the funding distribution for the case study projects.

Available Project Information

Information about the projects was obtained by reviewing the project documentation available from the FDOT Research Center. Although documents were not available for some of the projects, the available information was typically obtained from:

- **Original Proposals**
- **Project Progress Reports**
- **Project Final Reports**
- **Project Research Summaries**
- **Input from Project Managers and Principal Investigators**

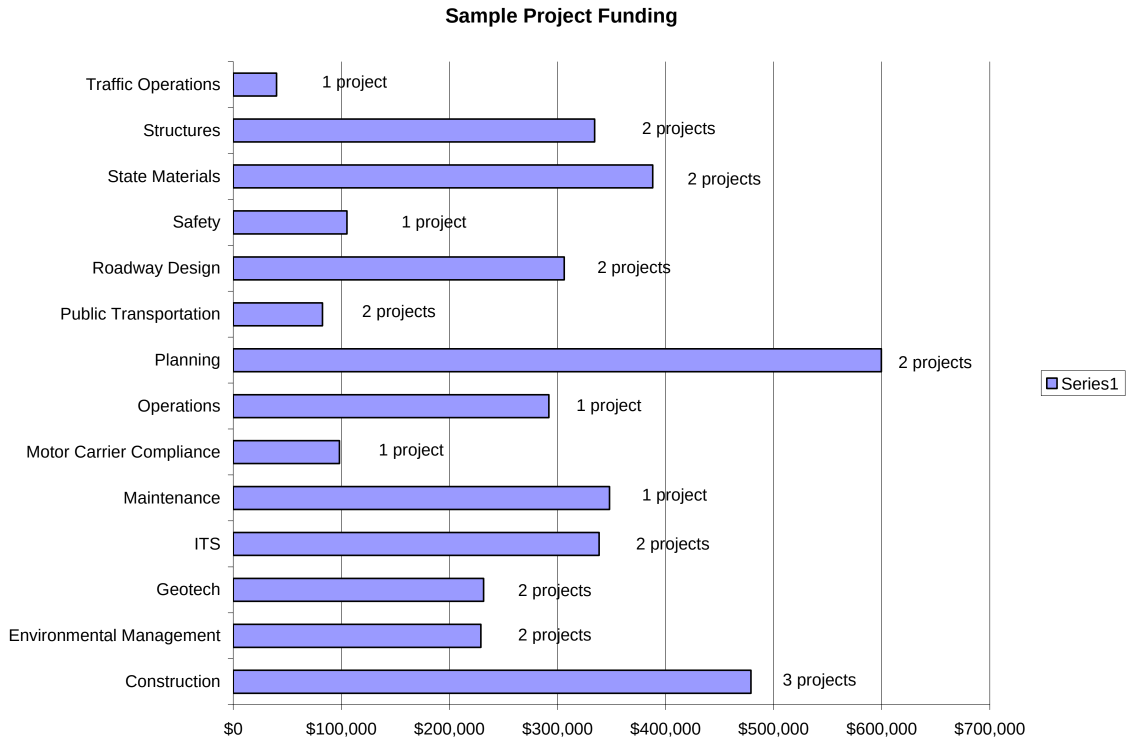

Figure 1 Distribution of Selected Projects by Functional Areas

Case Study Format

In the interest of consistency, a standard case study format was developed. Figure 2 provides the adopted format. Each case study was developed as a stand-alone document.

Survey of the Projects' Principal Investigators

In an attempt to obtain input from the project researchers, a survey was sent to each researcher and the corresponding FDOT research project manager assigned to the project. Figure 3 provides a copy of the survey document. Surveys were sent to 23 projects' principal investigators. Only 8 responses were received. One of the respondents refused to complete the survey.

Project Information

Title
Project Coordinator
Principal Investigator
Performing Organization
Period of Performance
Contract Amount
Categorization

Research Need Statement

Provide a clear description of the background situation and problem that this research is to solve.

Research Objectives

What is this study trying to accomplish? What will change?

Research Methodology

How is the research being conducted? What methods are being used?

Research Products

Specifically what products will be produced from this project?

Implementation

What implementation steps will be required to make use of the research products?

Research Benefits Assessment

Comprehensive benefit assessment including both economic and non-economic benefits.
Fully documented benefit evaluation process.

Figure 2 Case Study Format

FDOT
Research Benefits
Project Information Survey

The Florida Department of Transportation is committed to developing procedures for measuring and documenting the benefits of its research projects. There are many good reasons for this effort. One is the belief that continued research program funding is dependent upon the ability to demonstrate the benefits of the investment in research.

The University of Florida is contributing to this effort through its work on FDOT Project BD545-12, Development of Procedures for Estimating the Economic Benefits of FDOT Research Project Results. The scope of this project in part involves the development of case studies of a representative cross section of recent FDOT research projects. These case studies will tell the project story (needs, objectives, work effort, and results). The case study information will hopefully provide a foundation for developing methodologies for measuring research benefits. We believe that the case studies will be published in the BD545-12 project Final Report and possibly other publications.

The first step in developing these case studies is to obtain the basic project information from the Principal Investigators. We therefore request your assistance in providing this survey information. You will note that at the FDOT's request, the survey format closely matches the FDOT's current format for the submission of new project proposals. Please take a little time from your schedule and complete this survey form. Much of the narrative information can probably be taken from your project proposal. Please contact me if you have any questions. Thank you for your assistance.

Ralph D. Ellis, Jr., Ph.D., P.E.
Associate Professor
Department of Civil and Coastal Engineering
365 Weil Hall
University of Florida
Phone: (352) 392-9537 x1485
Fax: (352) 392-7983
Email: relli@ce.ufl.edu

Figure 3 Survey of Principal Investigators

Principal Investigator
Project Number
Project Title
Classification (Select from attached FDOT list)

Please classify this project:

Provides NEW knowledge (basic research) ☐ **Yes** ☐ **No**
Enhances EXISTING knowledge (applied research) ☐ **Yes** ☐ **No**
Technology transfer (not research) ☐ **Yes** ☐ **No**
Provides clarification of an issue(s) ☐ **Yes** ☐ **No**

Where is the expected application of the results *(indicate most appropriate)*:

- ☐ **Localized, e.g., project level**
- ☐ **Regionalized (with Florida)**
- ☐ **Statewide**
- ☐ **Regionalized (multiple states)**
- ☐ **National**

Does this project include *(check all that apply)*:

- ☐ **Software development?**
- ☐ **New products/materials development?**
- ☐ **Patentable products?**

Who will be affected by this project?

- ☐ **The sponsoring FDOT office (only)**
- ☐ **Other functional unit(s) within FDOT *(please list)***
- ☐ **Other identifiable group(s) outside FDOT *(please list)***

Level of impact on those most affected by this project's outcome *(indicate most appropriate)*:

- ☐ **Little/minor**
- ☐ **Somewhat important**
- ☐ **Very important**

Level of impact on the traveling public—will they <u>see</u> (visibility & interest) a difference? *(indicate most appropriate)*

Figure 3 Continued

- ☐ **None**
  - ☐ **Minor**
  - ☐ **Major**

Implementation will *(check all that apply)*:

- ☐ **Save the Department money**
- ☐ **Require more money**
- ☐ **Save time**
- ☐ **Require more time**
- ☐ **Reduce other resources**
- ☐ **Require more other resources**

How will the results be implemented? *(check all that apply)*

- ☐ **Policy changes**
- ☐ **Specification changes**
- ☐ **Procedure modification/development**
- ☐ **Process changes**
- ☐ **Other *(please specify)***

OR

☐ **It is anticipated that there will need to be more research before implementation can occur.**

What are the problems/issues if this project was not funded?

Figure 3 Continued[1]

[1] **Additionally, the survey requested Needs Statement, Objective and Approach, Payoff Potential, and Implementation information**

This survey included the same information that the FDOT now requires from anyone proposing a new research project. The low response rate for this study may be explained by the following issues:

- Researchers on currently funded projects have little incentive to provide additional information
- Surveys ask for information that the researchers have not developed
- Researchers do not wish to be pinned down or categorized with regard to project expectations and benefits

The Deployment Plan process is now about a year old. The current process should resolve original conflicts.

General Lessons Learned from Case Study Development

Most Projects Are Initiated by FDOT Functional Areas to Provide New Information or to Solve Perceived Problems Related to their Activities and in Support of Strategic Plans

For example, the designers are typically seeking to better understand specific design issues. The materials group is generally interested in subjects that connect with materials quality issues. The Safety Group is by and large interested in developing results that can be translated into improved safety.

Relatively Few Projects Are Initiated With the Primary Objective of Providing Economic Benefits

Although economic benefits sometimes result from research, most research projects are not undertaken with that end in mind. For example, of the 23 projects reviewed, not 1 project was specifically focused on economically benefitting the FDOT. Most projects are developed “to aid functional groups in performing their jobs better.”

Functional Areas Can Help Determine the Research Needs and Assess the Benefits

Given the range of technical issues involved, the FDOT Research Center does not have the resources to make informed decisions concerning needs or benefits. The people using the research products and possessing the technical expertise must be the ones to develop the needs and asses the benefits. The FDOT Research Center can, however, provide the process structure, incentive, and leadership for this through the Functional Areas. Additionally, the FDOT Research Center has a role to play in coordinating research efforts to avoid duplication of research on a state and national level. The Research Center continues to undertake initiatives to achieve these goals.

Implementation of Research Results Remains a Challenge

Although there are notable exceptions, implementation efforts typically begin after concluding the research contract. The researcher contributes to developing an implementation plan, but has limited ability to contribute to the actual implementation. The FDOT Research Center is addressing this issue by making a “Research Deployment Plan” a necessary component of every research project. Additional funds and contract arrangements were made to facilitate deployment efforts.

Quantifiable Economic Benefits Far Exceed the Cost Of Research

Figure 4 presents a summary of the benefit evaluation results for the case study projects. Slightly less than half of the projects (8 of 20) were judged by the researcher of this study to have produced significant economic benefits. However, the benefits could be quantified in only 20% (4 of 20) projects. All of the other projects produced significant non-economic benefits.

The total funding cost for the case study projects was $3,234,732. The estimated quantifiable economic benefits were $23,767,031. Considering only the quantifiable economic benefits, the benefit to research cost ratio is approximately 7 to 1. If the non-quantifiable economic benefits were considered the ratio would be significantly higher.

Economic Benefit Evaluations are Best Performed Jointly by the Principal Investigator and the FDOT Functional Area

Information is required from both sources; consequently, a joint effort before project closeout makes sense.

Non-Economic Benefits Should be Included in Project Benefit Evaluations

More than half of the case studies produced significant non-economic benefits rather than economic benefits, including advances in technical knowledge, quality of functional performance, safety, and other benefits. These non-economic benefits are valuable and should be considered.

Observations on Research Benefit from Functional Area Evaluations

Construction, Materials	**Research products from these areas are typically the easiest for measuring economic benefits. Results usually directly affect construction cost, which is very well documented in the FDOT system.**
Structures, Geotech	**The challenge here is that when an improved design approach is developed, the designers switch to the new meth Since each project is unique, cost comparisons can only be made by designing a project with the old and new method. Evaluating these studies may have to include this additional investment.**
Environmental	**Environmental economic benefits typically occur when research results provide for a more cost effective way to comply with regulati Benefits are measured by comparing previous compliance costs with new compliance costs.**
Operations, Planning-Policy, ITS	**These “softer” research areas offer the greatest opportunity for economic benefits. However,**

	quantifying economic benefits is difficult. Nevertheless, looking at the entire economic scope of their operations while crediting subjective improvements, such as improved quality, efficiency, and decision making, can give a relative indication of the potential benefit.

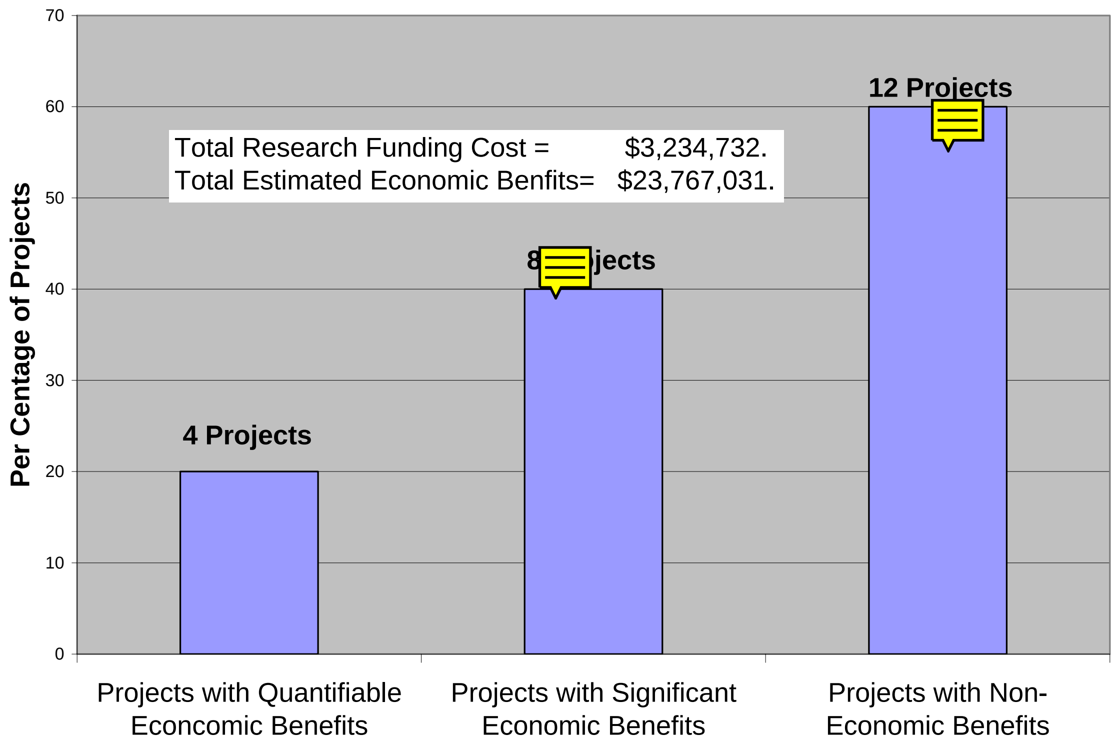

Figure 4 Benefit Evaluation Summary for 20 Case Studies

Table 1 Original Project List

No.	Project Title	Project Contract No.	Project Contract Amount	Planned Start Date	Planned Finish Date	FDOT Functional Area	FDOT Areas to Benefit
1	Development of Improved Procedures for Managing Pavement Markings During FDOT Highway Construction Projects	BC354-58	$78,727.00	11/16/2001	12/31/2002	Construction	Safety, Maintenance operation
2	Effect of Vibration on Concrete Strength During Foundation Construction	BC352-14	$46,666.00	6/4/2002	8/31/2003	Construction	Design, Quality control
3	Digital Video Boroscope for Drilled Shaft Inspection	BB279	$353,601.00	9/4/1997	6/1/1999	Construction	Quality control, Inspection
4	Comprehensive Review of Collected Noise Information at Barrier Sites	BC355-07	$50,000.00	8/7/2002	5/31/2003	Environmental Management	Environment
5	Erosion Control Along Florida Roadways	BC354-07	$179,150.00	10/7/1999	6/20/2002	Environmental Management	Environmental Maintenance
6	Determine Optimum Depths of Drilled Shafts Subjected to Combined Torsion and Lateral Loads Using the Centrifuge testing	BC354-09	$156,465.00	9/2/1999	9/20/2000	Geotech	Testing procedures, Planning
7	Determination of Axial Pile Capacity of Prestressed Concrete Cylinder Piles	BC354-60	$75,153.00	11/1/2001	6/30/2003	Geotech	Design
8	TNCC Validation and Enhancement	BC096-19	$113,533.00	11/4/2002	4/15/2004	ITS	Traffic (Highway) Operations
9	Central Florida Data Warehouse Phase 2	BC355-09	$225,000.00	9/20/2002	11/30/2003	ITS	Planning and Administration
10	Project Planning Models for Florida's Bridge Management System	BC352-09	$249,994.00	12/31/2000	1/31/2003	Maintenance	Cost Control
11	Proof of Concept for Simulation Based Re-Certification of Commercial Driver License	BD548-03	$98,261.54	7/30/2003	10/31/2004	Motor Carrier Compliance	Traffic (Highway) Operations, Capacity and Traffic Operations
12	Local Technical Assistance Program	BC354-39	$292,000.00	1/15/2001	12/31/2001	Operations	Planning

Table 1 Continued

No.	Project Title	Project Contract No.	Project Contract Amount	Planned Start Date	Planned Finish Date	FDOT Functional Area	FDOT Areas to Benefit
13	Improving Operation of FDOT Telemetered Traffic Monitoring Site	BC596	$259,740.00	4/12/2000	9/30/2002	Planning	ITS - Planning
14	Optimization and Implementation of Fiber Optic Sensors for Traffic Classification and Weigh in Motion Systems	BB038	$340,000.00	9/4/1997	11/30/1999	Planning	ITS - Planning
15	Quantifying the Business Benefits of TDM	BC137-23	$30,000.00	12/20/2000	12/31/2001	Public Transportation	Planning and Administration, Public Transportation
16	Inventory and Analysis of Advanced Public Transportation Systems in Florida	BC137-04	$52,500.00	12/16/1999	12/30/2000	Public Transportation	
17	Structure Induced Scour at Complex Bridge Piers	BC354-35	$40,000.00	10/30/2000	10/30/2001	Roadway Design	Design, Planning
18	Evaluation of Lab Testing Systems for Asphalt Mixture Design and Evaluation	BB888	$266,264.00	8/10/1998	5/1/2001	Roadway Design	Testing procedures
19	Updates of Florida Crash Reduction Factors and Countermeasures to Improve the Development of District Safety Improvement Projects	BD015-04	$105,279.00	12/14/2001	1/31/2003	Safety	Planning, Traffic Operations
20	Substitution of Cement Sources within a Mix Design	BC353-01	$159,807.38	9/15/1999	8/31/2000	State Materials	Material and Design
21	Nondestructive Testing for Advanced Monitoring and Evaluation of Damage in Concrete Materials	BC354-57	$228,305.00	11/16/2001	12/31/2003	State Materials	Testing and maintenance
22	Florida Pier Design Capabilities Development	BB295	$215,914.00	8/18/1997	10/14/1998	Structures	Design
23	Application of Fiber Reinforced Concrete in the End Zones of Precast Prestressed Bridge Girders	BC386	$118,361.00	9/20/1999	9/15/2001	Structures	Materials and Design
24	Capacity of the OOCEA Network of Toll Roads with ETC	BC096-15	$40,079.00	6/25/2001	7/31/2002	Traffic Operations	ITS, Operations

Chapter 3: Agency Economic Benefit Assessment Methods

Introduction

The following procedures for assessing economic benefits were developed to assist the research investigator and the agency project manager in estimating the probable economic benefits from implemented research results. These step-by-step methods have been developed within the context of the FDOT program; however, with adjustment they are transportable to other research programs.

These procedures apply to estimating economic benefits only. Not all projects result in economic benefits. Other benefit assessment methods should be used for quantifying non-economic benefits. We are approaching benefit assessment at or near the completion of a research study but prior to implementation. Assessing benefits after implementing a project would involve a direct review of actual cost differences as opposed to the estimation procedures presented here.

Examples of economic benefit calculations are provided in the Project Case Studies included in Appendix A. A comprehensive listing and review of FDOT cost and planning publications is included in Appendix B.

Step 1 Identify What is Expected to Change

Research findings and recommendations must be reviewed to determine the probable affect when implemented. If the results of a study are implemented and used by the FDOT, what will be different? Table 2 is a list of the most common changes that provide economic benefits. These generally fall within three categories:

Design Methods, Procedures, and Standards
Product or Work Process Specification for Purchased Products or Services
Planning and Operations Procedures

Table 2 Common Types of Changes Resulting in Economic Benefits

Change Category	Possible Economic Consequences	Example
Design Methods, Procedures, and Standards	**Design work-hours required to develop design are reduced. Design method produces more efficient design (reduced cost for designed feature). Design method results in more reliable or durable designed feature (reduced Life-Cycle Cost for designed feature). Design method offers a design feature that provides the public users of the design feature with savings.**	**Florida Pier software provides more efficient bridge substructure design methods. Substructure elements are more efficient, resulting in reduced construction costs for substructure systems on FDOT bridges.**
Product or Work Process Specification for Purchased Products or Services	**A different, more cost-effective product may be substituted. Product specification is modified. Required work process is modified.**	**HDPE pipe is recommended for use in certain applications. Product option results in reduced construction costs for drainage systems.**
Planning and Operations Procedures	**New information or tools improve user efficiency. New information or tools improves FDOT process efficiency.**	**Operations research results in improved operational management capabilities. Incident management procedures reduce congestion and road user costs.**

Step 2 Estimate the Unit Cost of the Activity or Product before the Change

Construction Costs

The FDOT Estimates Office maintains a historical database of the average unit cost for all construction pay items and also reports quantities installed. This information is available on the FDOT website at http://www.dot.state.fl.us/estimates/

This is the best source of information for historical costs on construction components. Figure 5 provides a representative view of the average unit price information that is available as a PDF file on the FDOT website.

Material Costs

Costs of materials purchased directly by the FDOT may be obtained from FDOT purchasing records. The location of the cost history will depend on the unit within the FDOT purchasing the product or requesting the purchase. For example, cost information on materials purchased by the State Materials Office (SMO) would be available from the SMO.

Consultant Services Cost

Contracts for consultant services, such as CEI and design, involve negotiations and budget discussions prior to contract formation. Additionally, these service type contracts involve periodic billing and accounting of work hours. Therefore, reviewing recent project records should provide reasonable estimates of time and cost for service activities. FDOT project managers working at the District level are a good resource for consultant cost information.

FDOT Labor Required for an Activity

Often, there may not be detailed time records for the activity within the FDOT system. Therefore, the estimator must consult with the people within the FDOT who perform this activity and with their supervisors. Exact records may not be available but estimates of average times can be developed with input from the group performing the work.

CESPO05 11/09/2004-09.44.04 Page: 7

Florida Department of Transportation
Item Average Unit Cost
From 2002/01/01 to 2004/10/31

Contract Type: ALL STATEWIDE
Displaying: VALID ITEMS WITH HITS
From: 0050 To: 1999999999

Item	No. of Conts	Weighted Average	Total Amount	Total Quantity	Unit Meas	Obs?	Description
0337 7 21	4	$115.28	$109,252.69	947.700	TN	N	ASPH CONC FC(INC BIT)FC-9.5PG76-22
0339 1	268	$112.35	$9,172,390.92	81,644.425	TN	N	ASPHALT PAVEMENT MISCELLANEOUS
0341 70	28	$.93	$2,605,334.74	2,806,899.720	SY	N	ASPHALT RUBBER MEMBRANE INTERLAYER
0350 1 1	1	$28.00	$2,856.00	102.000	SY	N	CEMENT CONC PAVT PLAIN (6")
0350 1 3	3	$95.01	$750,692.40	7,901.000	SY	N	CEMENT CONC PAVT PLAIN (8")
0350 1 4	3	$79.75	$256,702.29	3,218.670	SY	N	CEMENT CONC PAVT PLAIN (9")
0350 1 5	2	$73.73	$612,142.56	8,303.000	SY	N	CEMENT CONC PAVT PLAIN (10")
0350 1 10	4	$67.39	$855,262.20	12,692.000	SY	N	CEMENT CONC PAVT PLAIN (12")
0350 1 13	1	$245.00	$13,965.00	57.000	SY	N	CEMENT CONC PAVT PLAIN (11 1/2")
0350 1 19	1	$61.80	$10,220,607.60	165,382.000	SY	N	CEMENT CONC PAVT PLAIN (12 1/2")
0350 1 20	1	$30.00	$41,250.00	1,375.000	SY	N	CEMENT CONC PAVT PLAIN (VAR. 9 1/2" AVG)
0350 2 1	1	$40.00	$39,960.00	999.000	SY	N	CEMENT CONC PAVT REINFORCED (6")
0350 2 3	1	$85.00	$4,335.00	51.000	SY	N	CEMENT CONC PAVT REINFORCED (8")
0350 2 10	3	$77.89	$90,113.00	1,157.000	SY	N	CEMENT CONC PAVT REINFORCED (12")
0350 72	40	$3.65	$3,217,201.79	881,325.000	LF	N	CLEANING & RESEALING JOINTS
0350 78	18	$2.71	$233,852.79	86,248.000	LF	N	CLEANING AND SEALING RANDOM CRACKS
0352 70	14	$3.07	$2,048,956.90	667,194.950	SY	N	GRINDING CONCRETE PAVT
0353 70	12	$311.29	$9,550,281.60	30,679.393	CY	N	CONC PAVT SLAB REPLACEMENT
0354 70	7	$51.57	$107,086.00	2,076.600	SF	N	PATCH PORTLAND CMNT CONCRETE PAVMENT
0354 71	7	$6.33	$2,368,480.00	374,020.000	LB	N	CONCRETE PAVEMENT RESTORATION
0370 1	2	$106.17	$577,104.72	5,435.650	LF	N	BRIDGE APPR EXP JOINT
0400 1 1	2	$892.94	$129,806.50	145.370	CY	N	CONC CLASS I(CULVERTS)

Figure 5 Representative View of FDOT Average Unit Cost Listings

Step 3 Estimate the Unit Cost after the Change

Substituting a Product or Process with an FDOT Cost History

If the product of the research is the ability to substitute a different process or product currently in use, the FDOT cost data of the substitute item can be used to estimate the unit cost after the change. For construction related items, the FDOT Average Unit Cost history is the best source of cost data. For non-construction costs, the estimator must refer to FDOT procurement records.

New Unused Product or Process with No FDOT Cost History

If the proposed research product or process resulting from the research is new with no cost history, a detailed cost estimate must be developed. This involves estimating the quantities and unit cost of the materials, labor, and equipment required for the new item. Estimators should consult FDOT personnel with experience in the relevant process.

Step 4 Adjusting the Unit Cost for Inflation

Estimate precision is improved if future unit costs are adjusted for the expected effects of inflation. The most efficient way to do this is to use FDOT's published cost index. Current or previous unit costs are converted to future unit cost by applying the cost index factor. For example:

$$\text{Estimated Unit Cost (Year 2006)} = \text{Unit Cost (Year 2004)} \times \frac{\text{FDOT Cost Index (Year 2006)}}{\text{FDOT Cost Index (Year 2004)}}$$

Note that both the original and changed unit cost should be adjusted for future years. Figure 5 presents the FDOT Long Term Inflation Forecast as of March 5, 2005[2].

[2] Available from the FDOT Office of Financial Development

Step 5 Estimating Future Quantities

Useful Life
A five year useful life for the research benefit is recommended unless there is a strong indication that the benefits will have a longer life. Additionally, the five year life also matches the FDOT planning horizon.

Using FDOT Planning Information to Estimate Future Quantities
The FDOT publishes a variety of planning information, including the following:

Program Cost Projections (Right of way, Design, Construction, Safety
Transportation Funding Projections
General Planning Data (System Use Trends, Population Trends)

A complete inventory and description of published FDOT Cost and Planning Data is included in Appendix B.

Work Program Items
The FDOT maintains a work plan detailing planned construction activities for five years out. The plan is updated each year. Most estimates of future units can be made on the basis of the FDOT five-year work plan. For example:

$$\text{Estimated Units in Year 1} = \text{Units in Previous Year} \times \frac{\text{Program Budget for Current Year}}{\text{Program Budget or Year One}}$$

The number of units in the Previous Year is obtained from the FDOT Average Unit Cost publication. Program budget figures are obtained from FDOT planning publications. Note that estimate precision is improved by using the budget category most appropriate for the cost item. For example, the future quantity of foundation piling is best estimated using the budget category for bridges rather than using the whole work program budget. The same calculation is performed for years two through five.

For estimating future transportation user volumes, consult growth projections available in FDOT Planning publications.

Step 6 Calculating Total Estimated Economic Benefits

The basic process is to use the inflation adjusted unit costs and projected annual quantities to calculate an annual cost savings for each year of the five year projection. Figure 6 presents the base format for calculating total estimated economic benefits. If a total savings value in current year dollars is desired, the present value of each of the future year savings may be calculated by applying the appropriate present worth factor.

Florida Department of Transportation
Long Term Construction Cost Inflation Forecast
As of March 2005

FISCAL YEAR	FDOT PRICE TRENDS INDEX[1]		IMPLICIT PRICE DEFLATOR FOR STATE & LOCAL STRUCTURES[2]		CONSUMER PRICE INDEX	
1996	72.3	3.7%	85.44	3.7%	154.51	2.7%
1997	74.5	3.0%	87.98	3.0%	158.90	2.8%
1998	77.0	3.3%	90.93	3.3%	161.75	1.8%
1999	79.4	3.2%	93.83	3.2%	164.55	1.7%
2000	82.8	4.2%	97.76	4.2%	169.28	2.9%
2001	86.2	4.2%	101.88	4.2%	175.08	3.4%
2002	88.8	3.0%	104.95	3.0%	178.16	1.8%
2003	91.2	2.7%	107.73	2.7%	182.12	2.2%
2004	93.2	2.2%	110.08	2.2%	186.08	2.2%
2005	100.0	7.3%	118.14	7.3%	191.14	2.7%
2006	103.5	3.5%	122.61	3.8%	193.98	1.5%
2007	106.9	3.3%	124.60	1.6%	197.54	1.8%
2008	110.4	3.3%	126.52	1.5%	201.63	2.1%
2009	114.1	3.3%	128.66	1.7%	206.03	2.2%
2010	117.9	3.3%	131.02	1.8%	210.79	2.3%
2011	121.7	3.3%	133.67	2.0%	216.07	2.5%
2012	125.8	3.3%	136.65	2.2%	221.83	2.7%
2013	129.9	3.3%	139.69	2.2%	227.83	2.7%
2014	134.2	3.3%	142.57	2.1%	233.90	2.7%
2015	138.6	3.3%			240.15	2.7%

[1] Base year changed to state fiscal year 2004-2005, base year = 100. Historical years reflect annual inflation rates for the Implicit Price Deflator.

[2] Base year changed to calendar year 2000, base year = 100.

Source: Office of Financial Development - Florida Department of Transportation (used in the Florida Transportation Revenue Estimating Conference, March 2005).

Note: This is the current FDOT long-term forecast and is subject to change at anytime if the economy so indicates.

Figure 6 FDOT Long Term Construction Cost Inflation Forecast

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Adjusted Original Unit Cost (Adjust for inflation)	Orig Unit Cost Y0	Orig Unit Cost Y1	Orig Unit Cost Y2	Orig Unit Cost Y3	Orig Unit Cost Y4	Orig Unit Cost Y5
Adjusted New Unit Cost (Adjust for Inflation)		New Unit Cost Y1	New Unit Cost Y2	New Unit Cost Y3	New Unit Cost Y4	New Unit Cost Y5
Savings per Unit (Original Unit Cost - New Unit Cost)		Savings per Unit Y1	Savings per Unit Y2	Savings per Unit Y3	Savings per Unit Y4	Savings per Unit Y5
Estimated Unit Quantity (Developed from Planning Data)	Quantity Y0	Quantity Y1	Quantity Y2	Quantity Y3	Quantity Y4	Quantity Y5
Estimated Total Savings (Unit Savings x Estimated Units)		Total Savings Y1	Total Savings Y2	Total Savings Y3	Total Savings Y4	Total Savings Y5

Figure 7 Format for Total Cost Savings Calculation

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Appendix A Case Studies of Research Projects

Case Study No.	Project Title	Project Contract No.	Page No.
1	Development of Improved Procedures for Managing Pavement Markings During FDOT Highway Construction Projects	BC354-58	30
2	Digital Video Boroscope for Drilled Shaft Inspection	BB279	36
3	Determine Optimum Depths of Drilled Shafts Subjected to Combined Torsion and Lateral Loads Using the Centrifuge testing	BC354-09	41
4	Determination of Axial Pile Capacity of Prestressed Concrete Cylinder Piles	BC354-60	45
5	Project Planning Models for Florida's Bridge Management System	BC352-09	49
6	Local Technical Assistance Program	BC354-39	53
7	Optimization and Implementation of Fiber Optic Sensors for Traffic Classification and Weigh in Motion Systems	BB038	57
8	Inventory and Analysis of Advanced Public Transportation Systems in Florida	BC137-04	60
9	Structure Induced Scour at Complex Bridge Piers	BC354-35	63
10	Evaluation of Lab Testing Systems for Asphalt Mixture Design and Evaluation	BB888	67
11	Comprehensive Review of Collected Noise Information at Barrier Sites	BC355-07	70
12	Erosion Control Along Florida Roadways	BC354-07	73
13	Florida Pier Design Capabilities Development	BB295	76
14	TNCC Validation and Enhancement	BC096-19	79
15	Central Florida Data Warehouse Phase 2	BC355-09	82
16	Quantifying the Business Benefits of TDM	BC137-23	85
17	Proof of Concept for Simulation Based Re-Certification of Commercial Drivers License	BD548-03	88
18	Improving Operation of FDOT Telemetered Traffic Monitoring Site	BC596	91

Note: Copies of the case study final reports are available from the FDOT Research Center and can also be viewed on-line at:

http://www.dot.state.fl.us/research-center/ProjectInfo.htm

Case Study 1
Development of Improved Procedures for Managing Pavement Markings during FDOT Highway Construction Projects

Project Information

Project Manager
Sastry Putcha
(850) 414-4148
Email: sastry.putcha@dot.state.fl.us

Principal Investigator
Dr. Ralph Ellis.
(352) 392-9537
relli@ce.ufl.edu

Performing Organization
University of Florida
Department of civil and Coastal Engineering
365 Weil Hall / P.O. Box 116580
Gainesville FL, 32611-6580

Period of Performance
Start: 11/16/2001
Finish: 6/30/2003

Contract Amount
$78,727.00

Contract Number
BC354-58

Categorization
Construction

Research Need Statement

Highway construction frequently involves modifying the existing pavement markings. Maintenance of traffic plans typically consist of numerous phases, each requiring different routing of the traffic through the work zone. Existing thermoplastic markings must be removed and replaced with temporary markings that indicate the new lanes. Temporary markings must also be removed and replaced as different maintenance of traffic phases are implemented.

Current FDOT specifications do not allow the use of paint to cover or mark out existing pavement markings. Mechanical removals of the existing markings by water blasting or by grinding are the methods most often used for marking removal. However, both methods are relatively expensive and frequently do not produce satisfactory results. Mechanical removal frequently results in pavement scarring, which can be a serious problem. The pavement scars can easily be mistaken for pavement markings with wet pavement conditions at night or with the sun at the right angle to the pavement.

Work zone safety is a key concern. Safely navigating through a highway construction work zone places extraordinary demands upon the motorist. Construction activities and lighting can distract the motorist when they must negotiate temporary lane shifts and/or detours. Clearly, it is essential that the motorist not be confused or distracted by pavement markings that have not been properly removed.

Emergency closures on major roadways, such as interstate highways, present additional challenges. Pavement markings must be removed quickly and effectively. The current mechanical removal methods are not satisfactory for emergency situations.

Research Objectives

The objective of this research was to study the removal of pavement markings and to develop improved methods for removing temporary markings. The method must remove all traces of the markings and leave no pavement scarring that might be misleading to the motorist.

Research Methodology

The subject of this research was to investigate the feasibility of covering pavement markings rather than attempting to remove them from the pavement surface. The first approach the research team took was studying the seal coating method for the removal of pavement markings and then developing an appropriate method. This study applied manufacturer's seal coat materials over pavement markings according to manufacturer specification. The friction evaluation plan was developed and performed after the seal coat was applied.

FDOT's Pavement Friction unit (Locked-Wheel Skid Trailer) and the British Pendulum Tester were used for the seal-coated surface friction tests. Field tests were performed to evaluate friction performance and constructability.

The second approach involved developing a modified sand seal coating. In this method, a traditional sand seal application was modified by increasing the asphalt temperature and by using concrete fine aggregate. The increased temperature shortened the break time for the asphalt, and the angular sand improved the friction properties. A test section was installed on a construction project and Locked-Wheel friction tests were performed to measure friction performance. The suitability and durability of the covering were observed.

In addition, this research also investigated the feasibility of using removable marking tapes to remove pavement markings. 3M Removable Black Line Mask and ATM Black-Out Tape were installed at a project test site and their performance was evaluated.

Research Products

Three different removal methods were tested during this research: Coal Tar Seal Coating, Modified Sand Seal, and Covering Tape. The Modified Sand Seal method proved to be the most viable.

Modified Sand Seal Coat
The modified sand seal coating provided exceptional performance with regard to friction, coverage, and durability. The materials and equipment required for installation are normally found on paving projects. Cost estimates indicate that installing the modified sand seal coating will cost less than the current water blasting and grinding removal methods. Figure 1.1 provides a photograph of the modified sand seal installation.

Figure 1.1 Modified Sand Seal Application

Implementation

To implement any of these methods it is necessary to meet safety and practical requirements as well as any additional requirements established by the FDOT during any particular work. Among the most important requirements are the following:

- Meeting the Friction Test requirement for safety based on the FDOT's Pavement Friction unit (Locked-Wheel Skid Trailer) and the British Pendulum Tester
- Ensuring that the pavement marking cover would be durable and last longer than the work to be done in the area to avoid motorist confusion with old markings present in the pavement
- Maintaining a feasible method based on the importance of the road and the traffic conditions
- Noting the time required to install the pavement marking cover

Research Benefits

Analysis of the methods used to cover pavement markings showed that the sand seal covering and the covering tapes were more practical and successful than the seal coating method. The seal coating method adequately covered the pavement markings and obtained satisfactory friction test results. However, the main drawback was that several hours of set time was required before traffic could be allowed on the treated pavement. Additionally, the coal tar-based seal coating material is not organic to typical asphalt paving projects.

The sand seal covering method proved to be more practical and successful than the other two methods. Among the advantages offered by the sand seal covering method are the following:

- No scarring of the pavement
- Markings are completely covered and will not be mistaken for markings
- Materials and equipment required are already organic to most roadway projects and do not require the mobilization of specialized equipment
- Installation requires only 30 to 40 minutes of lane closure
- Covering is durable
- Asphalt paving may be placed directly over the covering
- Sand Seal Covering is less costly than current grinding or blasting methods

Estimate of Economic Benefits

The work activity basically involves two steps:

1. Application of asphalt with an asphalt distributor
2. Application of masonry sand with a truck equipped with a spreader

The high application rates for asphalt and sand have been used to develop the quantities. The asphalt application is identical to current paving activities; therefore, the current average bid price is used to estimate the cost of asphalt application.

The application of the masonry sand is estimated using the required crew components at current hourly rates.

Note that the estimate is based on a section of one lane width by 1500 LF and 1500 SF of paint striping to be removed. Also, the cost per unit is expected to be quantity sensitive. Greater quantities should result in lower unit costs. The estimated probable cost is $0.47 per LF.

What Will Change

Temporary pavement markings will be covered using the modified sand seal process instead of the current method of water blasting.

Original Unit Cost

From the FDOT Average Unit Cost reference, the average unit cost for pavement marking removal from January 1, 2002 to October 31, 2004 is $1.22 per SF. During this period a total of 478,234 SF or 168,788 SF per year were removed.

New Unit Cost

No cost history is available for the new method; therefore, the new unit cost must be estimated as follows. The cost estimating procedure involves developing the cost of a standard crew and the required materials. Note that the estimate is based on a section of one lane width by 1500 LF. In some situations, more than one marking line may be covered with a single pass, which would reduce the unit cost. Also, the unit cost is expected to be quantity sensitive. Greater quantities should result in lower unit costs. The estimated probable cost is $0.47 per LF.

Modified Sand Seal Cost Estimate

Mobilize and Setup	Quantity	Unit	Unit Cost	Total Cost	
Broom	1	Hr.	$12.16	$12.16	
Distributor	1	Hr.	$13.55	$13.55	
Dump Truck w/Spreader	1	Hr.	$51.99	$51.99	
Operators	2	Hr.	$38.00	$76.00	
Total Direct Cost					$153.70
Contractor Markup					$30.74
Asphalt Application					
Asphalt at Current Bid Average	216.67	Gals	$1.14	$247.00	
Item No. 030013 BIT MAT (Tack Coat)					$247.00
Apply Sand Seal					
Masonry Sand	5.80	CY	$24.00	$139.26	
Dump Truck w/Spreader	1	Hr.	$51.99	$51.99	
Operators	1	Hr.	$38.00	$38.00	
Total Direct Cost					$229.25
Contractor Markup					$45.85
TOTAL ESTIMATED COST		Job			$706.54
TOTAL ESTIMATED UNIT COST		SF			$0.47

Adjust Unit Cost for Inflation

Original and new unit costs are adjusted for inflation as follows. Note that the baseline year was selected as 2003 since the Average Unit Cost period included 2002 through 2004. The adjusted unit cost is the estimated cost developed in the preceding section. The yearly cost index values are from the FDOT Long-Term Construction Cost Inflation Forecast (See Figure 6, page 27).

	Year 0 2003	Year 1 2005	Year 2 2006	Year 3 2007	Year 4 2008	Year 5 2009
Cost Index	91.2	100	103.5	106.9	110.4	114.1
Inflation Factor	1.00	1.10	1.13	1.17	1.21	1.25
Adjusted Orig Unit Cost	$0.47	$0.52	$0.53	$0.55	$0.57	$0.59
Adjusted New Unit Cost	$1.22	$1.34	$1.38	$1.43	$1.48	$1.53
Unit Savings		$0.82	$0.85	$0.88	$0.91	$0.94

Estimate Future Quantities

In this case, we will use the FDOT's resurfacing budget category for projecting future paint striping removals. The calculation that follows uses budget figures from the FDOT Five-Year Work Program Plan (See Appendix B).

	Year 0	Year 1	Year 2	Year 3	Year 4	year 5
Budget (millions $)	$511.4	$720.8	$683.8	$729.0	$703.4	$650.2
Quantity SF	168788	237901	225689	240607	232158	214599

Calculate the Total Cost Savings

	Year 0	Year 1	Year 2	Year 3	Year 4	year 5
Quantity SF	168788	237901	225689	240607	232158	214599
Estimate Cost Savings per Unit		$0.82	$0.85	$0.88	$0.91	$0.94
Estimated Total Savings		$195,642	$192,095	$211,521	$210,775	$201,363

Case Study 2
Digital Bore Scope for Drilled Shaft Inspections[3]

Project Information

Project Manager
Dr. Sastry Putcha
(850) 414-4148
Sastry.Putcha@dot.state.fl.us

Principal Investigator
Kamal Tawfiq,
FAMU-FSU College of Engineering
(850) 410-6381
tawfiq@eng.fsu.edu

Performing Organization
FAMU-FSU College of Engineering
Tallahassee, FL

Period of Performance
Start: 9/4/1997
Finish: 6/1/1999

Contract Amount
$353,601.00

Contract Number
BB279

Categorization
Construction

Research Need Statement

To avoid contaminating concrete when pouring into a drilled shaft, and to improve shaft capacity, Florida Department of Transportation (FDOT) Specification 455-15.11.4 mandates that cleaning operations be adjusted "so that a minimum of 50% of the base of each shaft will have less than ½ inch [13 mm] of sediment at the time of placement of the concrete." Sedimentary deposits or any other debris at any place on the base of the shaft excavation may not exceed 1½ inches [40 mm]. If slurry is used, it must meet the

[3] **Adapted from a research summary prepared by Darrell Dockstader, FDOT Research Center**

requirements of Specification 455-15.8; and the sedimentary deposits or any other debris may not exceed 1 inch [25 mm].

For the last 20 years, FDOT has employed the Shaft Inspection Device (SID) to meet these requirements (Figure 2.1). FDOT currently owns two SIDs, each of which carries a replacement value of approximately $485,000. Additional annual expenses are incurred for the crane and crane operator, which are necessary to deploy the SIDs.

The FDOT annually inspects approximately 200 shafts with a shaft inspection device. Each inspection takes approximately four hours. The time and cost currently involved in shaft inspection is not optimal.

Research Objectives

The objective of this project was to develop an improved inspection device for drill shafts using video technology.

Research Methodology

In 1997, FDOT entered into a research contract with the Florida Agricultural and Mechanical University, Florida State University College of Engineering (Contract #BB-279), to investigate more cost- and time-effective means of conducting shaft inspections. The result was the Digital Video Boroscope (DVB), an optical device that can inspect the adequacy of the bottoms and the sides of drilled shafts. The DVB operates to a maximum depth of 300 feet.

Figure 2.1 FDOT Shaft Inspection Device (SID)

Research Products

Unlike the SIDs FDOT currently uses, the DVB is small and may be operated by one person. It is portable (Figure 2.2), takes only about 10 minutes to set up, and may be lowered either manually with a cable winch or with a compact motorized winch. The camera may be powered by a compact internal 12-volt rechargeable battery or by an external AC power source. A one-gallon clear water observation chamber gives unlimited inspection time over a large area at the bottom and sides of a borehole. The observation chamber is interchangeable (e.g., 6” or 8” diameter) to facilitate different viewing abilities. It also has a built-in metric scale for size proportion measurements of loose debris (Figure 2.3). Attached to the observation chamber is one or more calibrated, miniature, spring penetrometer(s) that can measure the thickness and the unconfined compressive strength of the bottom of a borehole.

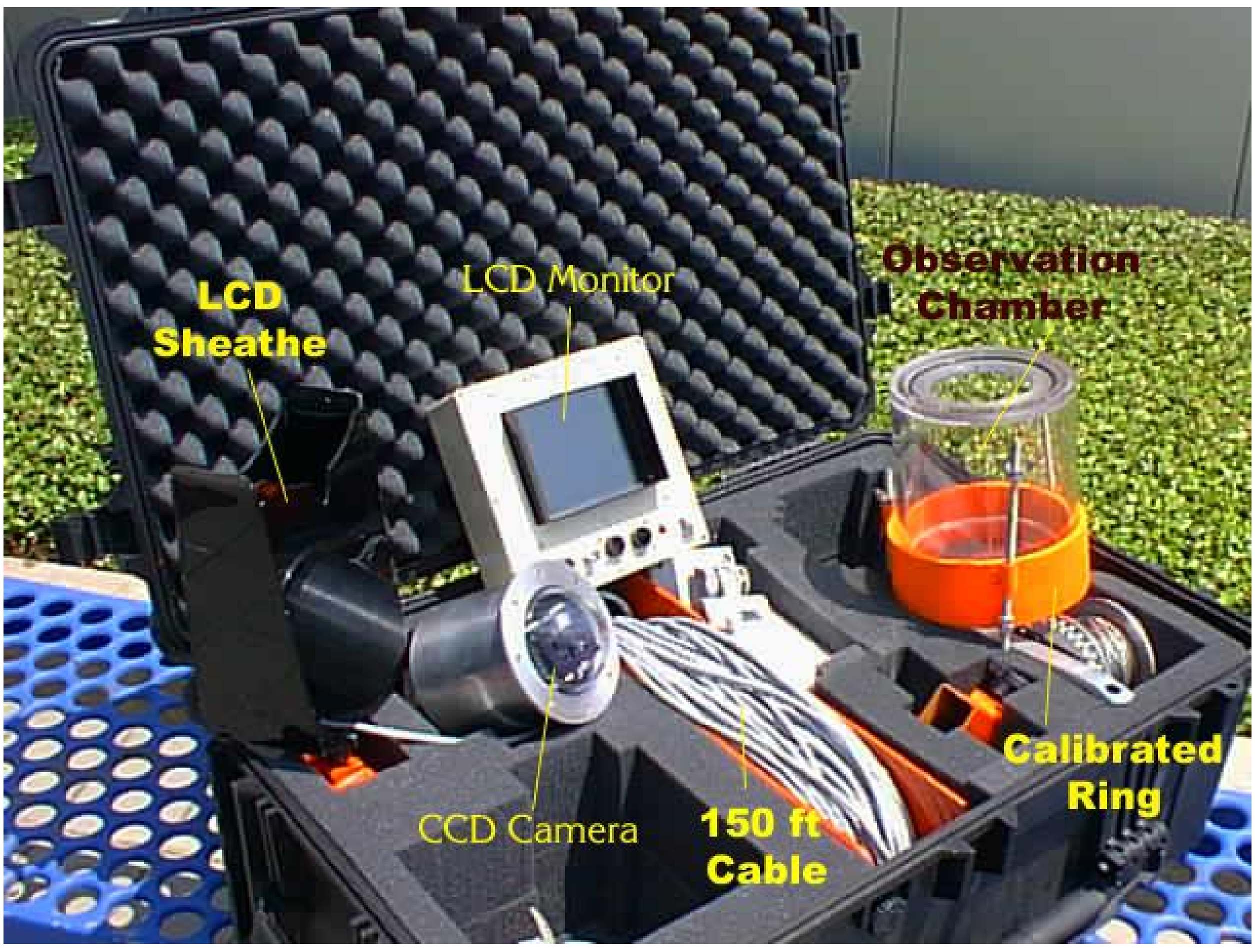

Figure 2.2 Digital Borescope

In its first of two design modifications, an LCD display unit replaced a larger, less portable monitor. Also, two different lowering devices are available. The first is a tripod, which may be used to lower the DVB into drilled shafts that have no steel casings. The second was built specifically to clamp onto steel casings, and it uses a rotating rod design (Figure 4) to facilitate ease of scanning.

Implementation

In March 1999, boroscopes were implemented in three districts. Reports detailing functionality of the device were submitted and led to design modifications to better facilitate use. The third model incorporated these changes and is currently being tested in the field.

Figure 2.3 Observation Chamber

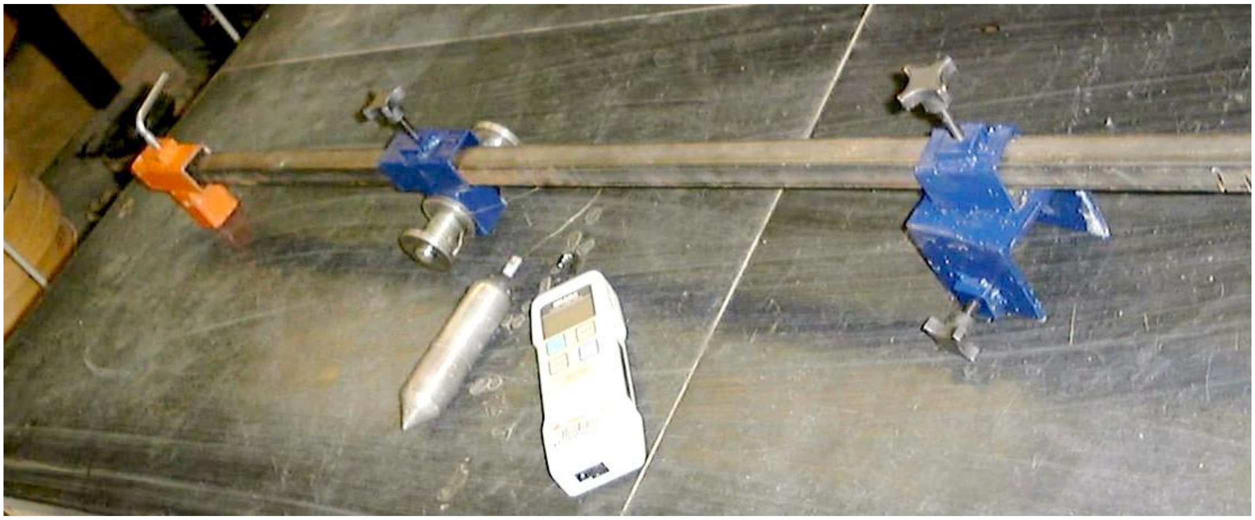

Figure 2.4 Lowering Device

Research Benefits

The benefit of the DVB, as it turns out, is that it has come to fill a niche for which there has not been a tool. The DVB has proven to be an excellent tool for smaller shafts and for checking the integrity of concrete pipe shafts, for example. Prior to the DVB, small shaft inspection was a rather inexact science. The SID could not fill this need, and the mini-SID, which was developed following the development of the DVB, does not have all of the functionality of the DVB. Side inspection will allow inspectors to check hollow pipe piles for defects resulting from driving or splicing.

Moreover, the mini-SID costs in the neighborhood of $75,000 and the DVB, at last reckoning, is expected to cost (as a production model) somewhere between $20,000 and $30,000.

Estimate of Economic Benefits

What Will Change
The FDOT will use the DVB for inspection of smaller drilled shafts and pipe piles. This is a job that the current SID does not do adequately. The DVB cost is less than half the cost of a comparable mini-SID. Savings are expected to be approximately $50,000 per unit.

Original Cost
The original unit cost of a mini-SID is approximately $75,000.

New Cost
The new production model cost of the DVB is expected to be approximately $25,000.

Case Study 3
Determine Optimum Depths of Drilled Shafts Subjected to Combined Torsion and Lateral Loads Using the Centrifuge Testing

Project Information

Project Manager
Peter Lai
(850) 414-4306
peter.lai@dot.state.fl

Principal Investigator
Michael McVay
(352) 392-8697
mmcva@ce.ufl

Performing Organization
University of Florida
Department of Civil and Coastal Engineering
365 Weil Hall / P.O. Box 116580
Gainesville FL, 32611-6580

Period of Performance
Start: 09/02/1999
Finish: 09/20/2003

Contract Number
BC354-09

Contract Amount
$156,465.00

Categorization
Geotech

Research Need Statement

FDOT high mast lighting and sign structures within coastal zones are designed with mast arms attached to poles and connected to drilled shaft foundations. Wind loads applied horizontally to the structures produce a side load (lateral load) and a twisting load (torsional load). For single-pole mast arm systems, significant lateral and torsional loads may develop on the foundation. Current Geotechnical Design practice is to uncouple the torsion from lateral loading. Typically, for lateral loading, Broms's design approach is applied, and, for torsion, one of four general FDOT methods is employed. Recently, however, both FDOT field-testing and the open literature has suggested that the lateral resistance of a drilled shaft is reduced when subjected to torque. Consequently, both experimental data and an integrated torque/lateral design method for drilled shaft design are needed.

Research Objectives

The purpose of this project was threefold:

1. Conduct multiple centrifuge tests on a mast arm/pole drilled foundation system subject to torque and lateral loading.
2. From the experimental results, evaluate current FDOT design practices for drilled shafts.
3. If necessary, modify current FDOT design practices for drilled shaft foundations subject to torque and lateral loading.

The objectives of the experimental work included the following:

- Investigate the influence of torque on the drilled shaft lateral capacity.
- For different construction practices, wet-hole or casing, identify and characterize any changes in the drilled shaft capacity.
- Identify the influence of soil properties (e.g., density and strength) and water tables on the foundation's lateral and torsional resistance.
- Characterize the effect of the shaft's geometry (e.g., the length to diameter (L/D) ratio) on its lateral and torsional capacity.

Research Methodology

The initial phase of the study was set up to vary the shaft's embedment ratios (L/D), soil properties, and lateral load placement (e.g., torque/lateral load ratio) in dry sands using steel casings in construction. The latter tests were considered optimum, resulting in the highest lateral and torsional resistance with minimal influence from construction. A total of 54 centrifuge tests were performed under t27 (two repetitions) different conditions (load application, shaft length, soil density, etc.).

Subsequently, a supplement to the original scope of service was processed to allow the research team to study the influence of construction and the water table. To characterize typical field installation, both mineral (bentonite) and polymer (KB) slurries were investigated. As noted in earlier field work (Tawfiq, 2000), torsional resistance of a drilled shaft was significantly impacted by the thickness of slurry cake during construction. Consequently, 35 additional centrifuge tests were performed to study the influence of shaft length, soil density, and load location under a variety of conditions in saturated sands.

The current FDOT design of drilled shafts subject to both torque and lateral load were validated/modified using the experimental centrifuge database. Since FDOT's current lateral design (Broms method) required monographs (charts) to distinguish short (soil failure) from long (pile failure) shafts, researchers wrote a MathCAD file to perform the analysis. The Broms lateral or FDOT torsional capacity methods were changed/modified, and the MathCAD file was changed/modified so that it could be used subsequently for design.

The final design (MathCAD file) was capable of sizing (length and diameter) a drilled shaft founded in one or two soil layers with variable groundwater depths, supporting a single mast arm/pole with point loading anywhere on the mast arm.For all centrifuge experiments, the shafts were constructed with cement grout and steel reinforcement, which extended up from the shaft to become the sign pole. All the shafts were placed and spun up in the centrifuge while the cement grout was fluid. The spinning allowed the stresses in the soil around the shaft to equilibrate to field values. The lateral loading commenced after four to five hours (once the cement grout hydrated).

The drilled shafts were installed in either dry or saturated fine sand (Edgar Florida) prepared at various densities (loose, medium, and dense) in both dry and saturated states. All of the shafts were constructed with either a casing (dry sand) or with a wet-hole (saturated sand) method of construction. For the wet-hole method, bentonite slurry was used to maintain hole stability, and the influence of slurry cake thickness was investigated. Researchers concluded that if the slurry cake was kept below 0.5 in. (prototype: field), little if any influence on the shaft's torsional capacity was found. However, when cake thickness approached 2.0 in. (field), a 50 percent% reduction in the torsional capacity of the shaft was observed.

When a load was applied to a pole, without torque, shaft lateral capacity increased with soil density and length to a diameter ratio (L/D) of up to five. Increasing a shaft's length to diameter ratio beyond five resulted in little if any lateral resistance due to flexure failure of the shaft. This behavior was predicted by FB-Pier, which matched the measured load vs. deflection for large movements. Researchers concluded that lateral resistance at small L/D ratios (e.g., close to three) was governed by soil density, while longer shafts (e.g., deeper embedments) with L/D ratios greater than five were controlled by flexure strength of shaft. Researchers found that, for dry and saturated sands, Broms ultimate capacity prediction generally was unconservative for the short shafts (L/D < 5) but better for long shafts (L/D >5). Effective prediction for the long shafts was attributed the magnitude of the assumed soil pressure distribution by Broms.

In the case of torsion on the drilled shaft (e.g., loading on the mast arm) all of the centrifuge experiments (dry and wet sand) revealed little, if any, influence of lateral loading on the torsional resistance of a shaft. A number of the current design methods used in the state of Florida, such as the Structures Design Office, District 7, District 5, FB-PIER, and Tawfiq-Mtenga methods, were compared to measured response. Results of the comparison revealed that all of the Florida Department of Transportation methods, including the Tawfiq-Mtenga method, are conservative, with FB-Pier as the least conservative (F .S. 1.2). Researchers also observed that, for all of the saturated sand deposits, failure occurred through torsion (including L/D =7) instead of lateral displacement. This fact was attributed to the significant reduction in vertical and horizontal effective stresses on the shaft due to a change from total unit weight to buoyant unit weight.

In the case of lateral capacity, the application of torque on the shaft had a significant impact on its ultimate lateral resistance. The lateral resistance reduction was very pronounced for high L/D ratios. Results were impacted little, if any, by soil density, but were significantly impacted by the torque to lateral load ratio.

Researchers used the results of the lateral load tests with torque to develop a model that predicts the decrease in lateral resistance as a function of soil density, L/D ratio, and torque to lateral load ratio.

As part of this research, a MathCAD program was written to check the design of the drilled shaft subject to combined torsion and lateral loading. Since Broms method was unconservative for short shafts, employed a simple soil pressure distribution, and could not handle multiple soil layers, a free earth support approach, as noted by Teng (1962), was used. The limiting lateral soil stresses on the shaft are those used for P-Y representations: Reese et al. (1978) for sand, and O'Neill et al. (1985) for clay. For short shafts (e.g., limit soil stress mobilized) maximum lateral loading on the pole is controlled by the soil properties. For longer shafts, the flexure capacity of the shaft limits the soil resistance. When torque is applied to the pole (e.g., loading along the mast arm), the soil pressure on the shaft is adjusted further downward from applying lateral load alone, as found with experimental data.

Since the experimental data revealed no influence of lateral loading on the torsional resistance of the shaft, the FHWA axial shear model (e.g., FB- Pier, District 5) model was also implemented in the MathCAD file. For all the experimental data, the MathCAD file was on average within 20%.

Implementation

The FDOT drilled shafts design process will need to be adapted to the proposed new model and will need to be approved by FDOT as the new method to obtain the drilled shaft depth when installing poles for the lighting and signs structures. This process will take some time until the FDOT reviews it and approves it for future use.

Research Benefits

This project improved the designer's understanding of drilled shafts subjected to combined torsional and lateral loads, showed that the torsional resistances of drilled shafts are independent of any applied lateral load, and proved that the current FDOT design for such loading is conservative. However, the lateral resistance of a drilled shaft subject to torque may be significantly reduced (depending on the torque-to-lateral load ratio), and the current FDOT (Broms) design approach may be unconservative. A new modified method (e.g., Broms method modified: MathCAD format) based on significant experimental work will result in safer high mast lighting/sign structures in Florida under hurricane loads.

It is expected that implementation of the knowledge gained in this study will improve the FDOT design of mast arm foundations, reducing the probability of future failures. However, the probability of past and future failures is unknown. The failure of a mast arm structure is conditioned upon the occurrence of an extreme event such as a hurricane. Therefore, it is not possible to make an estimate of the cost savings at this time.

Case Study 4
Determination of Axial Pile Capacity of Prestressed Concrete Cylinder Piles

Project Information

Project Manager
Peter Lai
(850) 414-4306
peter.lai@dot.state.fl

Principal Investigator
Michael McVay
University of Florida
(352) 392-8697
mmcva@ce.ufl

Performing Organization
University of Florida
Department of civil and Coastal Engineering
365 Weil Hall / P.O. Box 116580
Gainesville Fl, 32611-6580

Period of Performance
Start: 11/01/2004
Finish: 06/30/2003

Contract Amount
$75.153.00

Contract Number
BC354-60

Categorization
Geotech

Research Need Statement

The FDOT and its consultants have designed or are in the process of designing a number of bridge pier foundations with large-diameter (54 or 60 inches) prestressed concrete cylinder piles. This type of pile has a number of benefits when compared to smaller piles and drilled shafts. For instance, it has a much larger lateral moment of inertia than that of the smaller 30" piles and, consequently, will resist larger lateral loads (e.g., ship impact). Also, a cylinder pile will develop greater skin and tip resistance in sand and clays (but not in rock) than would a similar size drilled shaft (i.e., with a similar moment of inertia) due to the method of installation, such as being driven rather than drilled.

Recently, the FDOT updated its axial pile capacity assessment software (SPT97) to include prestressed concrete cylinder piles. In the new algorithm, the same unit skin friction and tip resistance curves as prestressed concrete piles are used. In the case of tip resistance, a number of assumptions were employed, but due to the unavailability of getting information at that moment it was not possible to verify these assumptions.

Therefore, given the benefits of large-diameter prestressed concrete cylinder piles over smaller solid piles and drilled shafts (in certain soil conditions), the FDOT needs to validate their current design approach (SPT97). Cylinder piles are typically available in diameters from 36 to 66 inches.

Research Objectives

The purpose of this project is the Determination of Axial Pile Capacity of Pre-stressed Concrete Cylinder Piles. With this engineering information, cylinder piles can be used to improve FDOT structural designs.

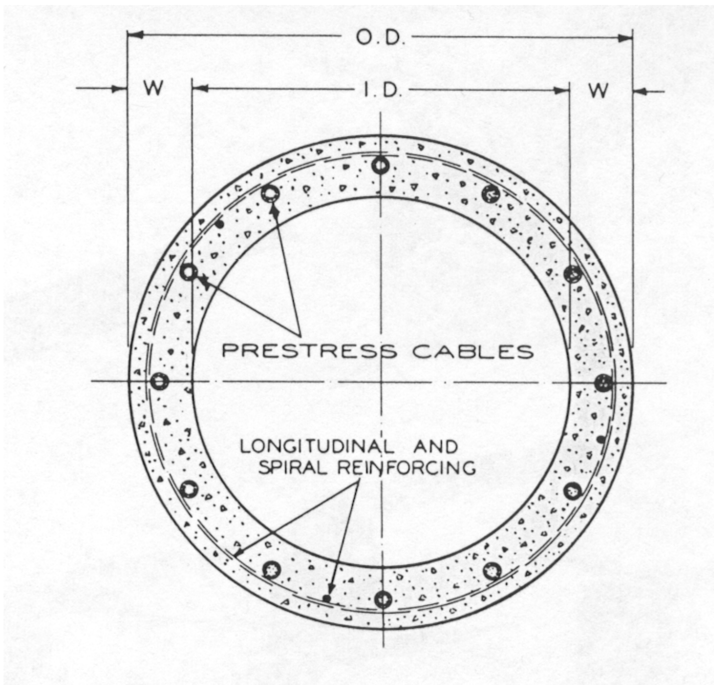

Figure 4-1 Cylinder Pile Detail

Research Methodology

This research involved the following steps:

Evaluating the Existing Soil Plug Theorem

Several existing design methodologies and their theorems were evaluated. A new analysis method and theorem was developed and validated using finite element computer modeling.

Collecting Information

Test data from old FDOT and consultant reports, and from other existing databases, were collected.

Classifying Information and Inserting Data

The collected data was grouped by soil type. It was then organized by predominate soil type as described in SPT97 (clean sand, plastic clay, mix soil, and rock). The data was then grouped into the predominantly single soil layers (sand, clay, etc.) and into multiple layers. Following classification, the data was inserted into the FDOT database.

Evaluating Unit Skin and Tip Resistance
Curves of unit skin friction and mobilized end bearing vs. SPT N values were developed using the database. The values were developed initially from piles inserted into single soil layers. The multiple layer deposits were subsequently used to validate the values.

Determining Soil Plug Depths
Different tip assessment approaches were investigated for plugging or forming the plug, i.e., qmob times total tip area or ring area vs. internal skin friction.

Evaluating COV
Evaluating the COV for the whole database allowed access to the LRFD’s ϕ (resistance factor) for cylinder pile design.

Figure 4-2 Cylinder Piles on an FDOT Project

Research Products

The research products include the following:

- An actualized FDOT database, based on soil type, in Microsoft Access.
- A report with Unit Skin, Tip Resistance, COV, LRFD’s □and soil plug depths evaluation.

Implementation

The results of the study were included in the software program FB-DEEP, which is the current design software used by the FDOT. It is also available as a research report for dissemination to interested parties.

Research Benefits

This project improved FDOT’s pile design software FB-DEEP by updating the design values applicable to cylinder piles. The expected outcome is improved substructure design when cylinder piles are selected.

This study provided an enhanced understanding of the design issues applicable to cylinder piles. This knowledge will improve the quality of FDOT foundation designs. However, economic benefits are not directly quantifiable at this time. In the future, as cylinder pile designs are selected for projects, comparative cost savings can be determined by comparing the cylinder pile cost to alternative approaches.

Case Study 5
Project Planning Models for Florida's Bridge Management System

Project Information

Project Manager
Richard Kerr
(850) 410-5757
richard.kerr@dot.state.fl

Principal Investigator
John O. Sobanjo
Florida A&M University – Florida State University College of Engineering
(850) 410-6153

Performing Organization
Florida State University
Department of Civil Engineering
2525 Pottsdamer St., Rm.129
Tallahassee, FL 32310
USA
Phone: (850) 410-6153

Period of Performance
Start date: 12/31/2000
End date: 09/30/2003

Contract Number
BC352-09

Contract Amount
$249.994.00

Categorization
Maintenance

Research Need Statement

The Florida Department of Transportation (FDOT) is implementing the AASHTOWare Pontis Bridge Management System (BMS) as a decision support tool for planning and programming maintenance, repairs, rehabilitation, improvements, and replacements for bridges on the state highway network. A BMS stores inventory and inspection data in a database, and it uses engineering and economic models to predict the possible outcomes of policy and program decisions.

Previous FDOT research in the areas of user and agency costs has identified the remaining analytical needs for implementation of the economic models in Pontis and has significantly advanced the development of these models. However, further work was needed to investigate several additional modeling issues and to develop methods for applying the results of the earlier research to FDOT bridge management decision-making. To make Pontis a valuable planning tool for FDOT bridge engineers, the development of a project-planning tool was needed. The project-planning tool required updated user cost models specific to Florida in terms of truck weight and height characteristics, and in terms of moveable bridge openings on Florida roadways.

Research Objectives

The project objectives included:

- The development of truck height models for user-cost modeling of bridges on Florida roadways.
- The development of truck weight models for user-cost modeling of bridges on Florida roadways.
- The development of user-cost models for moveable bridge openings on Florida roadways.
- The development of project-planning models for implementation in Florida's Bridge
- Management System, including software and a user's manual.

Research Methodology

The following tasks describe in detail the proposed services to be performed:

Task 1: Gather Relevant Data

Literature and final reports from previous FDOT user cost and agency cost studies will be reviewed.

Task 2: Identify Truck Height and Weight Models

This task includes working with pertinent FDOT offices and weigh-in-motion sites, collecting data that are unavailable from published sources, and analyzing these data.

Task 3: Develop User Cost Model for Moveable Bridge Openings

A user cost model for movable bridge openings will be developed to help justify replacement projects for its large inventory of movable bridges.

Task 4: Develop Project-Planning Model

A project planning model that incorporates the results of Tasks 2 and 3 and earlier FDOT research will be developed.

Task 5: Develop Implementation Assistance

Training to help users better-understand the computer model and research behind it will be developed.

Task 6: Prepare Final Report

A final report describing the study methods and results will be prepared. Recommendations for implementation of the results and for future research will be presented.

Research Products

This research will produce a project-level decision support software tool, a comprehensive user manual, and a final report. Figure 5.1 provides a graphic model of the project-level framework.

The software should by design incorporate network-level Pontis results along with all the products of the earlier research and provide FDOT bridge engineers with a clear picture of the economic health of a bridge and the economic implications of scooping and timing decisions for structure maintenance, repairs, rehabilitation, improvement, and replacement. The final report will describe the study methods and results, as well as recommendations for the implementation of results.

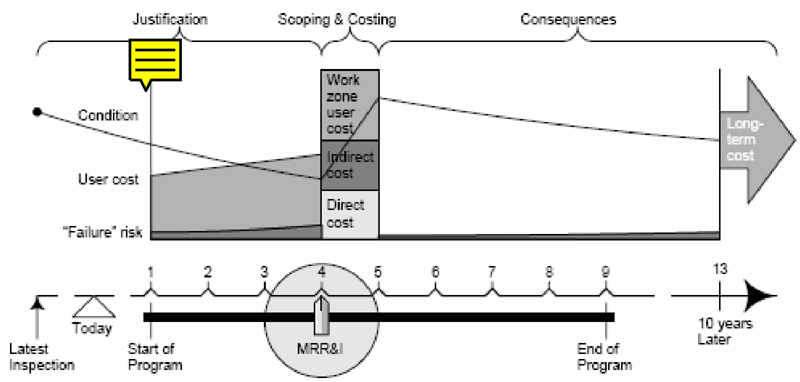

Figure 5.1 Project-Level Model Framework

Implementation

The project-level decision support software tool is available for dissemination as well as the user manual and the study report. The product is currently being used by FDOT maintenance sections.

Research Benefits

The developed decision support software, dubbed the Florida Project Level Analysis Tool, is highly graphical software that sheds light on the scoping and timing decisions inherent in bridge life cycle decision-making. This tool will aid in the implementation of several recent FDOT research efforts, such as Development of User Cost Data for Florida's Bridge Management Systems (WPI# 0510855) and Development of Agency Maintenance Repair and Rehabilitation (MR&R) Cost Data for Florida's Bridge Management System ([illegible]79) (available online at http://www.dot.state.fl.us/research-center/Completed_Maintenance.htm).

The Project Level Analysis Tool will also be used by the Department's Bridge Maintenance Offices during their selection of bridge repair and replacement projects. The tool will facilitate the quick screening of many projects, and will be useful in the selection of the most beneficial projects for further development. Consequently, it will improve the accuracy and the efficiency of the bridge repair and replacement work program. Because the tool developed in this project fills a significant gap in Pontis, other states have already expressed interest in implementing it.
The software tools developed from this research will assist the FDOT Maintenance section in bridge inspections and maintenance scheduling. It is reasonable to expect that

improved efficiency will result in cost savings; however, at this time it is not possible to quantify the potential savings.

Case Study 6
Local Technical Assistance Program

Project Information

Project Manager
Sandra Bell

Principal Investigator
Janet Degner
Phone: (352) 392-2371
Email: jdegn@ce.ufl.edu

Performing Organization
University of Florida
Florida Transportation Technology Transfer (T²) Center
Department of Civil and Coastal Engineering
365 Weil Hall / P.O. Box 116580
Gainesville, FL 32611-6580

Period of Performance
Start: 01/15/2001
Finish: 12/31/2001

Contract Amount
$292,000.00

Contract Number
BC354-39

Categorization
Operations/Planning

Research Need Statement
Much of Florida's transportation system is built and maintained by agencies other than the FDOT, such as city and county governments. It is important that these non-FDOT road systems be maintained at a high-quality level. These organizations need assistance in accessing the latest technical information and in training personnel.

Program Objectives
The objective of the Local Technical Assistance Program (LTAP) is to provide Florida's transportation and public works professionals with training and technical assistance in the best practices for managing their transportation infrastructure. The LTAP program is jointly funded by FDOT and the Federal Highway Administration (FHWA). Florida's center is one of 58 serving the United States, tribal governments, and Puerto Rico. The program is patterned after the U.S. Department of Agriculture's local extension service program. LTAP provides low- or no-cost, regionally available training to accommodate agency budgets and travel policies. The LTAP program is not a research program. It is, however, funded and administered through the FDOT research program.

The LTAP program has two main goals:

1. To establish a system to improve the exchange of information between local agencies, FDOT, FHWA, private transportation entities and universities.

2. To encourage implementation of effective procedures and technologies at the local level.

Program Activities

Program tasks are assigned by FHWA:

- Develop, arrange, and conduct a variety of topical professional training in many formats.
- Listen to constituents and develop programs to meet their needs.
- Publish quarterly newsletters and information brochures.
- Maintain a Media Center with publications and videos for loan covering every aspect of the road and bridge profession, with particular emphasis on safety.
- Provide the local agency link between state, national, and international research that is pending, current, or completed.
- Develop, participate in, and coordinate the distribution of a variety of transportation safety related programs and products.
- Develop, encourage, and implement strategies to create professional relationships that will enhance service to and by local agencies.
- Compile and maintain a membership database for newsletter and technical material distribution.
- Continually evaluate the effectiveness of the programs.

Program Benefits

The direct benefit of this program is improved care for Florida's transportation assets. Given the investment in and importance of the state's transportation infrastructure, improvements in maintenance and operation are valuable. The quantification of these benefits, however, can be difficult.

The following are representative examples of the Florida LTAP activity with cost benefits and implementation as direct results of LTAP activities:

1. The Florida T2Van program provides on-site training in over 30 subject areas. The cost benefit of this training is calculated for each session based on training costs charged by other organizations for similar instruction. In 2001, 184 T2Van programs were presented to 2,804 personnel with a cost benefit of more than $481,600.
2. One Product Demonstration Showcase (PDS) was held during the contract. PDSs are designed to provide a platform for local personnel to evaluate potential products or procedures for possible implementation by their agency. An agency that has successfully implemented a product may submit a request for holding a PDS to share the benefits of using the product with peer agencies. The format includes time for the agency personnel as well as contractors and vendors involved in a project to share their experiences with the product. Attendees can evaluate the performance of the product and ask questions of all who were involved. The PDS also offers the opportunity for site visits and real-time demonstrations. This involvement allows decision makers all the data and

technical field experience needed to determine if the product/procedure can be efficiently and effectively applied to their locale. Such evaluation processes and information sharing helps increase the success of decisions made by agency personnel. Attending agencies are contacted at a later date to see if they will proceed with or decide not to pursue their own implementation, based on the information gathered at the PDS event. If implementation occurs, the agency's financial investment applied to local roads is tracked. The Gulf Breezes Trail PDS was held and tracking has not begun as of the end of 2001.

Significant highlights for the 2001 year include the following:

- Trained 4,500 individuals in 26 live workshops, one Product Demonstration Program (PDP), one videoconference with 13 sites, and one international conference with 58 nations attending, for a total annual attendance of 1,631.
- Presented 184 T2Van programs to 2,804 personnel with a cost benefit of more than $481,600.
- Continued the Basic Math Refresher Self-Study Program with 32 continuing students and 18 new students enrolling during the year and completing 54 units or sessions.
- Continued the English Self-Study Program, which served 72 students, nine of whom were new, who completed 11 units or sessions.
- Continued partnerships with FACERS, FSITE, and APWA by assisting with and presenting workshops and technical meetings.
- Added 45 videos, 172 publications, and 12 cds to the lending library.
- Loaned 1,721 items that were viewed by 5,404 individuals.
- Completed and distributed updated library resource catalogs on demand.
- Published four 20-page newsletters and distributed 78,041 copies.
- Experienced a net increase of 440 entries to the mailing list.
- Revised and updated several T2Van modules.
- Published a new T2Van program brochure.
- Added a second training development coordinator as our center expands the diversity of instruction to satisfy agency training needs.
- Discussed training opportunities during on-site visits to evaluate agency needs.
- Continued to serve as coordinator for FACERS Awards Program.
- Debuted and maintained the FACERS.org Webpage.
- Continued refining the LTAP database to better track services and customer needs.
- Continued to serve as officers and hold committee positions of leadership and support for various local, state, and national organizations such as FACERS, APWA, Community Traffic Safety Teams, and the APWA/LTAP Clearinghouse.
- Received a visit from the FHWA/LTAP manager as a part of a nationwide center visit program to discuss issues, opportunities, and business practices.
- Chosen by FHWA International Programs Office to twin with kwazulu-Natal, South Africa, and also worked with Nigeria and Jamaica.
- Continued to expand the T2 Website.

Additional activities funded separately from LTAP and integrated into the T2 Center:

- Hosted the International Symposium on Transportation Technology Transfer with 58 nations attending.
- Continued to develop the Transportation Industrial Alliance.
- Presented 146 Traffic Safety classes (303 days) to 1,910 persons for the calendar year.
- Continued to assist the state's Community Traffic Safety Teams (CTST) and their activities with articles in our newsletter.
- Conducted single- and multiple-subject training sessions for participants through the Rural Transit Assistance Program (RTAP).
- Conducted Florida Child Passenger Safety Program classes and child safety seat checkpoint events.
- Updated three computer-based training modules.

Case Study 7

Optimization of Implementation of Fiber Optic Sensors for Traffic Classification and Weigh-in-Motion Systems

Project Information

Project Coordinator
Gordon Morgan
(850) 414-4730

Principal Investigator
P.J. Consentino
Florida Institute of Technology
Email: cosentin@fit.edu

Performing Organization
Florida Institute of Technology
Civil Engineering Program
150 West University Blvd.
Melbourne, FL 32901

Period of Performance
Start: 9/4/1997
Finish: 10/18/2000

Contract Amount
$340,000.00

Contract Number
BB038

Categorization
Operations

Research Need Statement

The FDOT needs to collect information on the type, size, weight, speed and density of traffic for proper maintenance and operation of highway systems. Currently the FDOT uses a combination of electromagnetic loops, piezoelectric sensors, and data acquisition systems to obtain classification and weigh-in-motion data. Maintenance records indicate that the piezoelectric sensors are subject to corrosion and damage from traffic. Additionally, the sensors are subject to interference from traffic in adjacent lanes and power surges.

Fiber optic technology offers the potential to eliminate the current maintenance and reliability problems.

Research Objectives

The objective of this research was to design, construct, and deploy fiber optic traffic classification and WIM sensors. The system must be capable of detecting the presence and number of vehicle axles in the desired traffic lane for input into standard FHWA classification software. Output signals must be capable of functioning with WIM Systems. Deployment had to include sufficient time to prove that the technology is ready for general implementation.

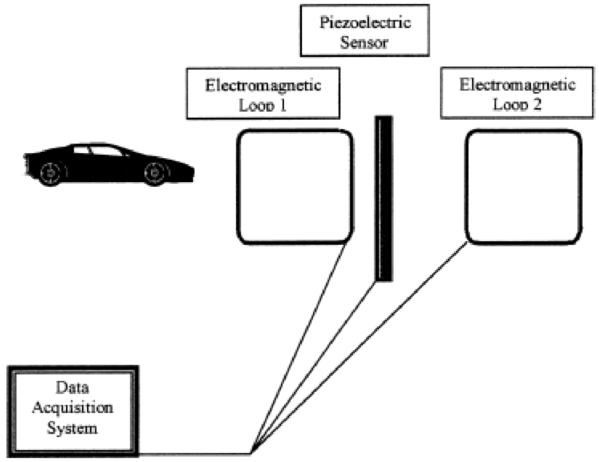

Figure 7.1 Typical Piezoelectric System for Vehicle Classification and WIM

Research Methodology

Nearly 50 fiber optic microbend sensors were placed in five field sites in Brevard County, Florida. Four of the sites had flexible pavement and one site had rigid pavement. The sensors were 6 feet long and had fiber optic leads. Sensors were encapsulated with relatively soft material that was not temperature sensitive. A falling weight deflectometer test was conducted to verify the accuracy of the sensor signals. Several laboratory tests to determine sensor characterization were also performed. Laboratory data was obtained with regard to:

- Load verses light loss under static and dynamic loads
- Load verses light loss under pneumatic loads

Additionally, scanning electron microscope examination of the sensor fibers indicated that the fiber used in the sensors would fail at approximately 700kPa (100psi).

Research Products

This study has produced a design for fiber optic traffic sensors. These sensors have been tested and are ready for implementation in FDOT traffic classification sensing systems.

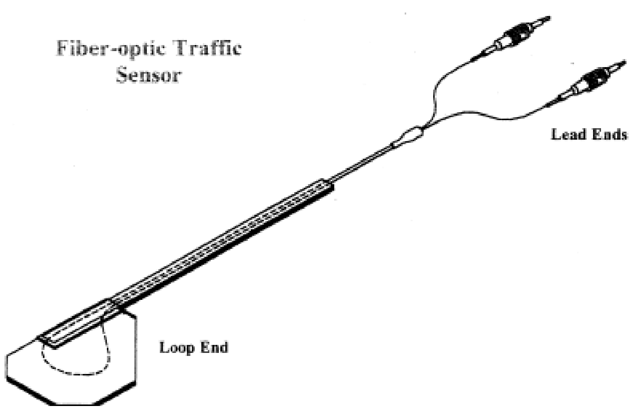

Figure 7.2 Fiber Optic Traffic Sensor

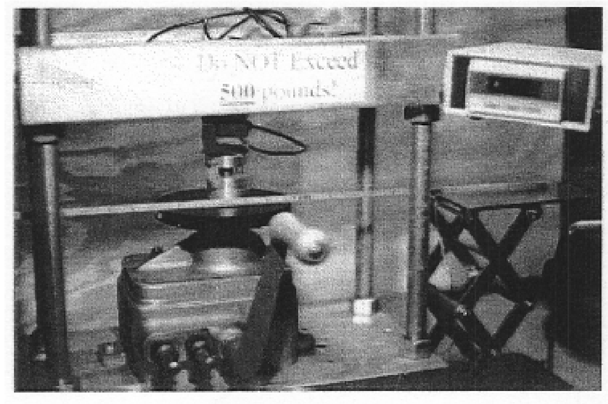

Figure 7.3 Laboratory Testing of Fiber Optic Sensors

Figure 7.4 Field Testing of Fiber Optic Sensors

Implementation

Durability problems are an obstacle to implementation.

Research Benefits

The sensors failed to perform well in one important area. The axle sensors were developed, but as portable sensors they were not permanent. Both types of sensors were plagued by durability problems. None of the prototype permanent sensors have lasted more than a few months, and the portable sensors couldn't be re-used. Durability issues must be resolved before benefits can be recognized.

Case Study 8
Inventory and Analysis of Advanced Public transportation systems in Florida

Project Information

Project Coordinator
Ike Ubaka
(850) 414-4520
tara.bartee@dor.state.fl.us

Principal Investigator
Joel R. Rey
(813) 974-3120

Performing Organization
Center for Urban Transportation Research
University of South Florida
4202 E. Fowler Avenue, CUT 100
Tampa, FL 33620-5375
(813) 974-312

Period of Performance
Start: 12/16/1999
Finish: 9/30/2001

Contract Amount
$340,000.00

Contract Number
BB038

Categorization
Operations

Period of Performance
Start: 12/16/1999
Finish: 9/30/2001

Contract Number
BC137-04

Contract Amount
$52,500.00

Categorization
Public Transportation

Research Need Statement
One element of the U.S. Department of Transportation's initiative on Intelligent Transportation Systems (ITS) is the Federal Transit Administration’s Advanced Public Transportation Systems (APTS) program. This program was established to encourage the use of technology to improve the quality and usefulness of public transportation and ridesharing services. Much of the current APTS activity in Florida has been initiated and implemented at the local level. An inventory and analysis of APTS in Florida was needed to help the FDOT develop baseline information on ITS transit activities around the state.
Research Objectives
The primary objective of the project was to develop an inventory of current and planned public transportation systems within Florida. Two secondary objectives included the following:
Performing a literature review of 10 major issues encountered by transit properties during deployment.
Conducting a transit system benefit assessment for a few selected agencies.
Research Methodology
The following tasks were performed to achieve the defined objectives:
Task 1: Researchers utilized several surveys and held stakeholder meetings to develop an inventory of the APTS activities going on around the state and compile the thoughts and comments of transit agency personnel and various statewide stakeholders regarding APTS in Florida. Thirty Florida transit agencies that receive or will receive FDOT block grant funding were identified with the assistance of FDOT's Public Transportation Office for inclusion in the study. A mail-back inventory questionnaire was sent to these transit agencies. The inventory questionnaire asked the transit agencies about five main technology areas in APTS, including fleet management, traveler information, electronic fare payment, transportation demand management, and technologies associated with paratransit providers. Nineteen of the 30 transit agencies responded to the questionnaire. Subsequently, a follow-up questionnaire was administered to all of the transit agencies via telephone and e-mail. Ten agencies participated in this follow-up effort.
Task 2: Researchers utilized a review of available literature to provide a variety of information on ten specific issues (e.g., ITS Architecture & Conformity, Funding, Institutional Arrangements, Procurement, and Public Involvement) related to the development and/or deployment of APTS. Using the results of the follow-up APTS inventory survey and the stakeholder meetings, they documented the experiences that a number of Florida transit systems reported with regard to these issues,
Task 3: Researchers conducted an assessment of the annual time savings benefits that five case study transit systems have accrued for their respective passengers through the implementation of one or more of three different APTS technologies: electronic fare collection, AVL, and bus priority. The spreadsheet-based, sketch-level analysis tool, SCRITS (Screening Analysis for ITS), was utilized to conduct each system’s analysis, which examined pre- and post-deployment conditions for each technology in use (or soon to be used) by each system.
Research Products
This study provides FDOT with the baseline information that it will need as it becomes more involved in the development and deployment of APTS throughout Florida. Secondarily, it is anticipated that this study will provide some level of guidance to transit

agencies in Florida, and in other states, that are in the formative stages of APTS investigation. Thus, this inventory and analysis of APTS in Florida is designed to help the FDOT gain a better understanding of the current ITS transit activities being undertaken around the state.

Implementation

This study provided the FDOT with additional information that it may use in developing future public transportation policy and programs. Implementation simply involves making the research report available to the appropriate personnel.

Research Benefits

Although only 19 transit agencies responded to the survey, the information obtained will be useful to FDOT planners. The data obtained provides a fair representation of the utilization of APTSs within Florida. In addition to providing FDOT with the baseline information on APTS deployments in Florida, the findings of this study on the growing level of APTS activities around the State helped provide the impetus and support for the implementation of a statewide APTS technical assistance program in 2002. This FDOT-sponsored program, known as the Resource for Advanced Public Transportation Systems (RAPTS), provides technical assistance to Florida transit systems in the planning, procurement, and deployment of APTS technologies through the Center for Urban Transportation Research at the University of South Florida. Some of the agencies that have received or are currently receiving technical assistance under this program include Volusia County Transit System, Jacksonville Transportation Authority, Miami-Dade Transit Agency, Palm Beach County Transit, Central Florida Regional Transportation Authority, Hillsborough Area Regional Transit, and Gainesville Regional Transit System.

Case Study 9
Structure Induced Scour at Complex Bridge Piers

Project Information

Project Manager
Rick Renna
(850) 414-4351
rick.renna@dot.state.fl.us

Principal Investigator
D. Max. Sheppard
(352) 392-1570
sheppard@ufl.edu

Performing Organization
University of Florida
Department of Civil and Coastal Engineering
345 Weil Hall / P.O. Box 116580
Gainesville Fl, 32611

Period of Performance
Start: 10/30/2000
Finish: 4/30/2003

Contract Amount
$40,000.00

Contract Number
BC354-35

Categorization
Roadway Design

Research Need Statement
The prediction of sediment scour depths at bridge piers is a necessary part to the design of the pier foundations. Most of the larger piers are complex in shape, they are usually composed of a column, a pile cap, and a pile group. The methodology and the accuracy of design scour depth prediction for complex piers needed to be improved. Existing methods and equations were based strictly on clearwater scour laboratory data. There is a need to evaluate if these methods could be applied in the high-velocity, live-bed scour range. Improved design for scour depth prediction results in foundation cost savings in most cases, and in safer bridges when existing methods under-predict scour depths.

Research Objectives
The objectives of this research included the following:

- Obtain more laboratory data (and extend the range of the important parameters) about sediment scour generated by the components of complex piers.
- Simplify and improve the accuracy of the methodology for predicting design scour depths at complex piers.

Research Methodology

Data for this analysis was obtained from experiments conducted by the researchers at the University of Florida and by J. Sterling Jones at the FHWA Turner Banks Laboratory. This research applies to structures that are composed of up to three components, as shown in Figures 1 and 2. In this report, these components are referred to as the column, the pile cap, and the pile group. The research method consisted of obtaining bridge scour data, analyzing the data, and developing, improving, and simplifying methods for predicting equilibrium scour depths.

Research Products

The product of this research is an improved method for predicting equilibrium scour on bridge piers. The functional dependence of the effective diameter for each component on its shape, size, and location has been established empirically through numerous experiments performed by J. Sterling Jones at the FHWA Turner Fairbanks Laboratory in McLean, VA, by D. Max Sheppard in the Hydraulics Laboratory at the University of Florida, and in the Hydraulics Laboratory at the Conte USGS-BRD Research Center in Turners Falls, Massachusetts.

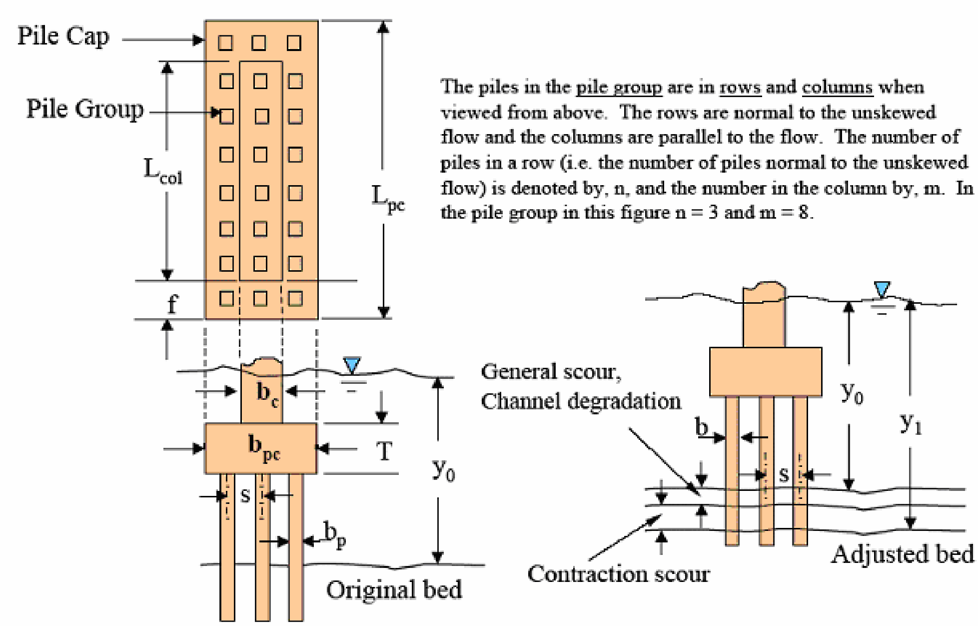

Figure 9.1 Complex Pier Definition Sketch

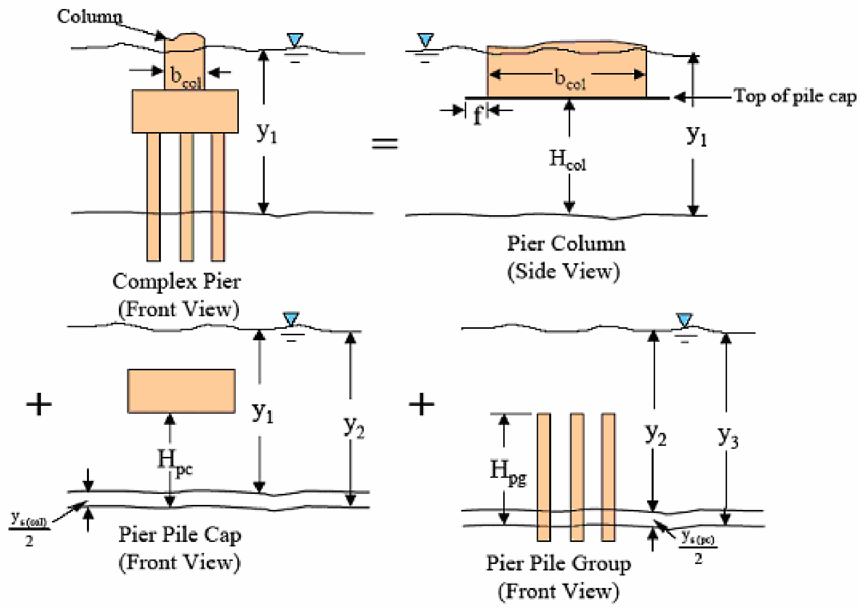

Figure 9.2 Complex Pier Structural Components

The methodology developed is only for estimating Local Scour Depth. General scour, aggradations and/or degradation, and contraction scour depth must be established prior to using this procedure. The information needed to compute local scour depth at complex piers is summarized below:

- General scour, aggradations and/or degradation contraction scour depth
- The external dimensions of all pier components, including their positions relative to the unscoured channel bed
- Sediment properties (mass density, median grain diameter, and grain diameter distribution)
- An estimate of relative roughness (roughness height divided by the media grain diameter)
- Water properties (mass density and dynamic viscosity)
- Water depth and depth average flow velocity just upstream of the structure

The local scour depth procedure involves decomposing the structure into its components (up to three), computing the scour depth produced by each component (starting with the uppermost component and working down), and summing these depths. Adjustments to both the bed elevation and the depth average velocity are made after each component scour is computed. As stated al[illegible], the local scour depth at the composite pier is the sum of the scour depth for the individual components.

Implementation

FDOT has reviewed and approved the proposed method and equations for predicting equilibrium scour depth. They are now provided online as a procedure, and designers are required to use them to design complex bridge piers. They can also be used to evaluate vulnerability to the scour of existing bridges. These equations will make the design process easier and more accurate when predicting scour depth. More information on this procedure may be viewed online:

http://www.dot.state.fl.us/rddesign/dr/Bridge%20scour/Fla%20Complex%20Pier%20Proc.htm

Research Benefits

The primary value of this research resides in its contribution to knowledge in an important design area. The product of this research is an improved methodology for predicting bridge scour depths, and more efficient design methods will result in safer and more cost-effective designs. However, scour is only one factor to be considered by the bridge designer. It is therefore difficult to predict the potential cost benefits of this research with any reasonable precision. However, previous scour prediction methods over-estimated scour depths. Designers believe that the new methodology may reduce substructure cost up to 30% on bridge structures where lateral loading is critical. Savings will vary with every design (and for exact savings to be determined on any given bridge, comparative designs would need to be produced (i.e., one using the old methodology and one using the new methodology).

Case Study 10
Evaluation of Laboratory Testing System for Asphalt mixture Design and Evaluation

Project Information

Project Coordinator
Bruce Dietrich
(850) 414-4318
bruce.dietrich@dot.state.fl

Principal Investigator
Reynaldo Roque
Phone: (352) 392-7368
Email: rroqu@ce.ufl.edu

Performing Organization
University of Florida
Department of Civil and Coastal Engineering
345 Weil Hall / P.O. Box 116580
Gainesville Fl, 32611

Period of Performance
Start: 8/10/1998
Finish: 12/30/2003

Contract Number
BB888

Contract Amount
$266.264.00

Categorization
Roadway Design

Research Need Statement

The design and production of asphalt mixtures resistant to cracking and rutting continue to be a top priority in Florida. Asphalt mixture rutting is generally an immediate and costly failure, as is the pavement rehabilitation cost in Florida for pavement cracking, which generally appears later in the pavement's life.

The Superpave volumetric design procedure, which uses a different compaction method to produce laboratory specimens, has improved the Marshall method of mixture design. It is widely recognized among pavement engineering communities that a physical test is required to verify the results of volumetric design. However, Superpave Level 1 does not perform any physical test on the asphaltic mixture to determine whether or not the volumetric design would actually result in a mixture with suitable resistance to rutting or cracking. Therefore, the principal focus of this research is to identify an appropriate laboratory-testing system that will evaluate cracking and rutting resistance, which is crucial to the successful design and production of an asphalt mixture.

Research Objectives

The goal of this study is to identify the most effective laboratory-based testing system for the design and production of asphalt mixtures that resist rutting and cracking in Florida. Specific objectives include the following:

- to conduct a detailed review of potentially suitable laboratory-based testing systems that evaluate the rut-resistance of asphalt mixtures;
- to define how the most appropriate and promising testing system would fit into an overall strategy to design and produce a rut-resistant asphalt mixture;
- to conduct a preliminary laboratory evaluation of the most promising testing systems;
- to obtain data on some Florida mixtures known for their rutting performance; and
- to provide input based on the research obtained to any national efforts that may be aimed at identifying a testing system for evaluation of rutting resistance.

Research Methodology

An evaluation of existing testing systems was conducted to identify the system that holds the greatest potential for success, followed by a laboratory-based evaluation of those systems. The project tasks were as follows:

Task 1: Comprehensive Review of Potential System

Task 1 included a review of the literature and other sources to cover all the tests previously used. Researchers identified the advantages and disadvantages associated with each type of system and explored the potential uses and deficiencies for different aspects of the asphalt mixture design, evaluation, and production processes.

Task 2: Identification of Most Promising Approaches and Testing System

One or more potential approaches to establish an effective and implementable system for the design and production of rut-resistant mixtures was identified. The most appropriate promising test identified would be used with the approach selected.

Task 3: Set-Up Testing System

The most promising equipment and testing system were identified.

Task 4: Evaluation of the Most Promising Approaches and Testing System

This task involved evaluating the capabilities of the system selected. It was accomplished electing an asphaltic mixture of known performance and conducting a series of tests.

One of the main goals of this task was to gain experience with different systems, especially with respect to their capacity, and to evaluate the materials used in Florida for which performance is known. This experience allows Florida to lead in the development sting systems that may be used at the national level.

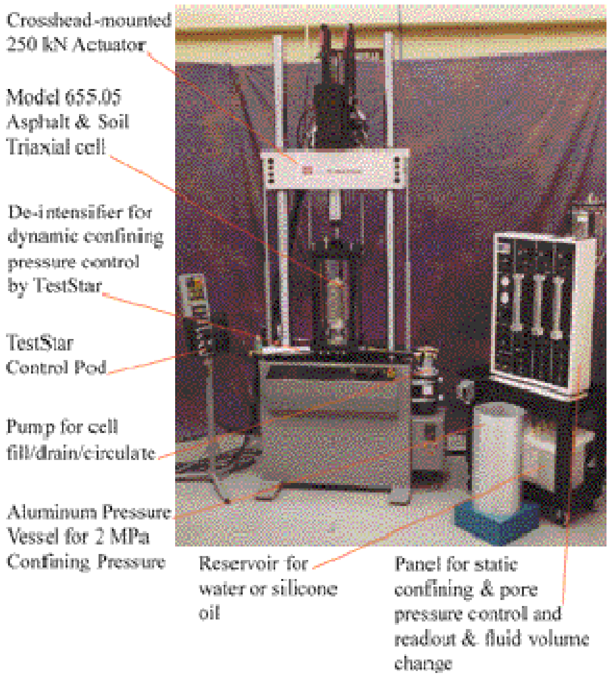

Figure 10.1 Proposed Laboratory Test Equipment

Research Products

This research project produced a final report on the most effective laboratory-based testing system that will aid in the design and production of an asphalt mixture that resists rutting in Florida.

Implementation

The Materials Office of the Florida Department of Transportation can immediately implement the results of this research to evaluate the rut-resistance of mixtures used throughout Florida.. This research will also pave the way for the development of a system to design and produce asphalt mixtures that resist both rutting and cracking.

Research Benefits

This project produced an enhanced laboratory testing system for asphalt mixtures. The technology is expected to improve the FDOT's management of asphalt mixture quality as well as improve the quality of FDOT's pavement design and installation. It is not possible at this time to quantify that improvement; however, pavement rehabilitation is a significant cost item for the FDOT. Because of the magnitude of the cost, any significant improvement will produce major economic benefits.

Case Study 11
Comprehensive Review of Collected Noise Information at Barrier Sites

Project Information

Project Manager
Mariano Berrios
(850) 414-5250
mariano.berrios@dot.state.fl.us

Principal Investigator
Roger Wayson
(407) 823-2480
wayson@mail.ucf.edu

Performing Organization
University of Central Florida
Community Noise Laboratory
Civil and Environmental Engineering Department
P.O. Box 162450
Orlando, Fl, 32816

Period of Performance
Start: 8/7/2002
Finish: 7/31/2003

Contract Amount
$50,000.00

Contract Number
BC355-07

Categorization
Environmental Management

Research Need Statement

Noise barrier walls are frequently used on FDOT highway right-of-ways to reduce the traffic noise impact on people in adjacent living units. However, the effectiveness of noise barrier design and construction was rarely measured. Consequently, design methods had not been adequately verified. There was a need to perform comprehensive noise information measurements and evaluations to improve understanding of the performance of different noise barrier structures and to improve design methods. Noise measurements were previously made at 19 noise barriers in a previous FDOT research study. Further analysis and evaluation of the previously collected data was needed.

Research Objectives

The primary focus of this research was to further evaluate previously collected noise data with regard to current noise prediction design modeling methodologies. Specific objectives included the following:

- Determining the narrow band capabilities of the Traffic Noise Model (TNM) traffic noise prediction model (1/3 octave band).
- Continuing to develop a shadow zone length prediction model using site-specific characteristics.

- Evaluating the TNM model prediction accuracy when using actual site meteorological conditions rather than default FHWA values.

Research Methodology

The project effort was divided into two major sections:

1. Analyzing the narrow band data previously obtained, including a review of ground effects and atmosphere effects and a comparison of the data to the Federal Highway Administration TNM predictions.
2. Developing a new method for estimating shadow zones behind noise barriers, the goal of which was to provide more reliable predictions of barrier effectiveness.

Research Products

This study provided in-depth analysis of measured effects of noise reduction barriers in Florida. Researchers reviewed the design modeling process, compared it to measured field data, and developed software to visualize shadow zones behind barrier walls. Also, researchers found that TNM-predicted reference spectra, above the barriers, were similar to the measured values, and that high-frequency effects caused by refraction from meteorological conditions are not significant for calm wind conditions and short distances.

The research products included the following:

- A new method of predicting shadow zone length behind barriers that uses data readily available to FDOT. The new method permits shadow zones to be estimated based on actual measurements that include background sound level contributions.
- A new method of background source allocation.
- Software that involves visualization of the soundscape and the shadow zone behind the barriers.

Figure 11.1 provides a representative example of the sound pressure predictions from TNN. Note that in this example plots indicate large amounts of red area due to the high source levels from Interstate 95 and the fact that the barriers were somewhat ineffectual due to their height.

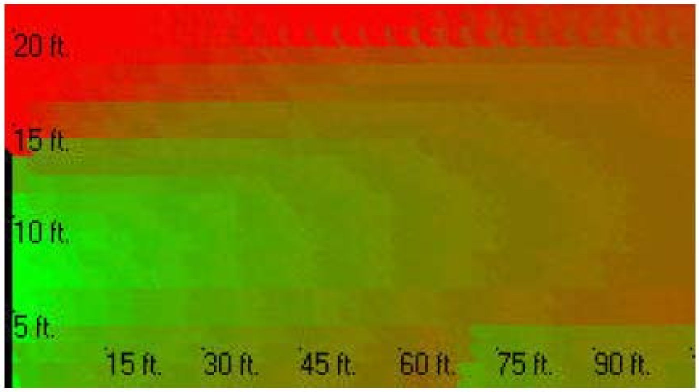

Figure 11.1 Sound Pressure Plot (Effective Wall Height 13.1 ft.)

Implementation

The knowledge gained and the software developed through this study has been made available to FDOT traffic noise analysts and designers, and is currently in use.

Research Benefits

This project significantly advanced the level of knowledge concerning sound barrier wall performance and provides improved methods for predicting barrier performance. The products of this study will assist FDOT traffic noise analysts and designers in developing more accurate predictions of barrier wall effects. These improved methods may result in gains in design efficiency and overall cost savings. For example, more precise estimates of sound barrier performance will permit more efficient designs.

Case Study 12
Erosion Control along Florida Roadways

Project Information

Project Contact
Joshua Boan
(850) 414-5266
joshua.boan@dot.state.fl.us

Principal Investigator
Robert Black
University of Florida
(352) 392-1835.
rjb@gnv.ifas.ufl.edu

Performing Organization
Institute of Food and Agricultural Science
University of Florida

Period of Performance
Start: 10/7/1999
Finish: 9/20/2002

Contract Amount
$179,150.00

Contract Number
BC354-07

Categorization
Environmental Management

Research Need Statement
Controlling erosion and sediment along roadways is often an important maintenance activity. Organic vegetative waste, which is a normal by-product of roadside right-of-way maintenance activities, can contribute to sediment and erosion control best management practices. However, there is a need to understand the best methods for using the organic by-products of roadside vegetation management to control erosion.

Research Objectives
The objective of this project was to determine the most effective ways of using the vegetation waste from roadside maintenance activities to improve roadside plantings. The specific objectives included the following:

- Developing best practices for using composted vegetation waste to help control erosion and sediment along roadways.
- Determining the effectiveness of biosolid compost as a fertilizer in improving poor roadside grasses.
- Developing standards and specifications for FDOT for the use of composts to maintain roadside plantings.

Research Methodology
The research involved the following major efforts:

Erosion and Sediment Control Study
The experiment consisted of using composted yard waste as mulch to stabilize steep slopes. Two sites were selected: Crescent Beach at SR206 and I-95, and Kissimmee at US27 and US192. The soils of the test sites were initially 4% organic and 95% medium sand. Slopes were approximately 26 degrees. Initially, turf grass (Bahia grass and Bermuda agrass) covered approximately 20% of the Crescent Beach site and 45% of the Kissimmee site. The test plots were treated with a variety of mulching and planting combinations. Irrigation watering was supplied by the FDOT maintenance forces during the study. The test plots were not mowed and received only minor weeding during the study. The percent covered and visual quality was estimated by two raters each month.

Fertilization Study
The second study involved applying composted biosolid materials as fertilizer on existing stands of Bahia and Bermuda grass at two locations. Treatments consisted of applying the compost at varying application rates.

Research Products

This project improved the FDOT's knowledge concerning the use of composted biosolids in their roadside maintenance program. Specific findings include the following:

Erosion and Sediment Control Study
Composted yard waste can help control erosion but does not necessarily facilitate the growth and establishment of turfgrass or other vegetation.

Composted yard waste can provide slope stability for periods of at least 18 months.
At one site, sod and erosion mat treatments had greater turfgrass and vegetative growth than the mulched plots. At the other site, the mulched plots performed better.

Fertilization Study
Composted biosolids provided greater living vegetative cover when used as a top dressing than the use of a soluble fertilizer or no fertilizer.

Drought conditions during the study revealed that the availability of water appears to be the most critical factor in vegetative growth (i.e., as opposed to fertilizer).

Implementation

The study resulted in suggested specifications, and print and visual aid materials for use by FDOT maintenance and construction personnel.

Benefits

This study demonstrated the value of using composted yard waste in establishing roadside turfgrass seed plantings. When applied as mulch, the yard waste improves the chemical and physical properties of the soil. Additionally, the application of mulch reduces erosion on slopes.

Case Study 13
Florida Pier Design Development Capability

Project Information

Project Coordinator
Mohsen Shahaw
(850) 414-2966

Principal Investigator
Marc Hoit
University of Florida
(352) 392-9537
mhoit@ce.ufl.edu

Performing Organization
Department of Civil and Coastal Engineering
University of Florida

Period of Performance
Start: 8/18/1997
Finish: 8/30/2000

Contract Amount
$215,914.00

Categorization
Structures

Contract Number
BB295

Research Need Statement

The design of complex bridge substructures previously involved an iterative process in which each step was calculated separately. The analysis of one trial configuration might require weeks of time and result in inefficient designs. Therefore, bridge designers needed an integrated design software tool that would allow them to efficiently design bridge substructures.

Research Objectives

In 1992, a research team at the University of Florida developed a unified software program that could perform a three dimensional soil-structure analysis and upgraded the program periodically. The objective of this research project was to improve the design capabilities of the current Florida Pier software.

Research Methodology and Products

The research focused on adding the following capabilities to the design package:

Apply loads to the free length of the pile.
The application of loads to the node in the free length was added to the new interface. Hidden nodes were also added to the interface to simplify the load application.

Allow pile properties to change along the length of the free length.
Previously, the pile properties could change along the length of the piles. There was a restriction that free length must have a constant cross section. This new option allows the cross section to change anywhere within the pile, including the free length.

Add a new structure type of BENT.
The previous program handled pile groups connected by a pile cap, but these piles can be connected with batter in any direction. In addition, a structure consisting of any number of vertical (non-battered) columns and a pier cap can be placed on top of the pile cap.

Specify different properties for each pile.
Currently, the program requires all pile in a pier to be the same cross section. The cross section is allowed to change along the length of the pile, but must remain the same for all piles. This new option would create pile sets, with each set meeting the current specification of any number of cross sections along the length of a pile. Thus, this option allows different pile properties for any pile (which is good for retrofit as well as the pile bent), as well as different pile lengths in a group.

Add the result print for intermediate (free length) pile sections.
The current analysis engine applies concentrated loads to the free length of the pile. However, these have to be added by hand and are not handled by the generator. This option will allow the intermediate pile results of the sections within the free length to be printed.

Research Benefits

These modifications will result in the easy creation and analysis of pile bent piers. In addition, piles with different cross sections permit the analysis of structures with damaged piles or retrofit operations where different piles are added to existing structures. Different pile cross sections will also enhance the Florida Pier's ability to analyze any pier structure for retrofit since the option will function for any pile group.

FLPIER has significantly improved structural design efficiency on FDOT bridge structures, and FDOT designers conservatively estimate that FLPIER has resulted in a 25% reduction in substructure cost. This project has contributed in part to these benefits.

Substructure cost historically averages between 6% and 10% of the total project cost. The following estimate of cost savings is based upon the FDOT-planned major bridge projects for the next five years.

	Year 0	Year 1	Year 2	Year 3	Year 4	year 5
Budget (millions $)	$326.10	$142.60	$163.60	$118.80	$199.00	$168.70
Estimated Substructure Cost (millions $)	$26.09	$11.41	$13.09	$9.50	$15.92	$13.50
Estimated Savings (millions $)	$6.52	$2.85	$3.27	$2.38	$3.98	$3.37

Thus, the results of this research are saving the FDOT and other DOTs millions of dollars each year.

This software tool has facilitated other important research as well like the St. George Island Barge Impact Research, which will greatly improve knowledge of the dynamic effects of vessel impacts. This research will be incorporated into the FBPIER software and will afford for the first time a consistent and realistic approach to the analysis of the nonlinear dynamic vessel to bridge impact phenomenon.

Case Study 14
TNCC Validation and enhancement

Project Information

Project Contact
Liang Hsia
(850) 410-5615
liang.hsia@dot.state.fl.us.

Principal Investigator
Radwan Essam
(407) 823-4738
aeradwan@mail.ucf.edu

Performing Organization
Department of Civil and Environmental Engineering
Center for Advanced Transportation Systems Simulation
University of Central Florida

Period of Performance
Start: 11/4/2002
Finish: 8/1/2004

Contract Amount
$ 113,533.00

Categorization
Traffic Operations

Contract Number
BC096-19

Research Need Statement

Traffic bottlenecks, both in number and in severity, influence the performance and/or level of service of toll networks. However, design improvements can increase the performance and the capacity of toll networks. Models, such as the Toll Network Capacity Calculator (TNCC), can be used to compute the number of vehicles that can pass through a highway segment with a toll facility and, thus, provide valuable information for choosing lane configurations at toll facilities. The information generated by the TNCC can be useful for a variety of planning and organizational purposes, and directly supports the FDOT's overall mission: to use the information to manage special events or for planning or design purposes.

Research Objectives

The primary objective of this research project is to integrate the TNCC into a Decision Support System (DSS) with a Graphical User Interface (GUI). The TNCC is a model for computing the maximum number of vehicles that can pass through a highway segment containing a toll collection facility. A secondary objective is to demonstrate the practical application of TNCC's DSS.

Research Methodology

Modeling traffic at toll collection facilities has led to the development of an appropriate standardized performance measure for toll plazas, No-Queue-Maximum-Throughput (NQMT). Current microscopic and macroscopic models of toll facilities either compute outputs too slowly or make too many assumptions that lead to inaccurate outputs. Most are not generic enough to deal with a wide variety of situations and plazas, therefore, they are of limited usefulness. For given traffic characteristics such as the Electronic Toll Collection (ETC) usage rate and percent-trucks, NQMT is the maximum throughput in vehicles per hour at a plaza with a given lane configuration such that no queues exists in any of the lanes at the end of the hour.

This research worked with two very different hybrid models for traffic at toll collection facilities, SHAKER and Toll Network Capacity Calculator (TNCC), which differ in the resolution of their results (SHAKER providing a higher resolution output but, consequently, taking much longer to calculate results). Both were implemented in java programs to predict NQMT. These models can be used to understand how throughput and other performance measures are dependent upon (1) the characteristics of the traffic approaching the plaza, (2) the lane configuration of the plaza, and (3) the properties of the traffic categories, such as processing rates for the different categories. Both models were calibrated with actual data on a network of toll roads maintained by the Orlando Orange County Expressway Authority (OOCEA). In addition, SHAKER is self-calibrating, so that it can be customized to predict the NQMT of any plaza in any arbitrary region after making the proper field measurements of the processing rates of the identified categories of traffic at that plaza.

Both models were made accessible by a login onto a DSS website hosted by the University of Central Florida; however, the DSS only integrates TNCC with hourly maps of the OOCEA network of toll roads. The maps have subdivided the OOCEA's highways into 299 highway segments, 20 of which contain toll collection facilities. These maps indicate by color-code which segments on the Network are bottlenecks, are nearing bottleneck condition, or are potential bottlenecks. The capacity of every segment, except for these 20 segments, was calculated using the Highway Capacity manual (HCM) 2000, the standard for computing capacities for different types of highway segments and compared to the approach volumes. The NQMT, computed by TNCC, was used as the capacity values for the other 20 segments containing toll collection facilities; and these were then compared to the approach volumes to the plazas. If the approach volumes were larger than the capacity, the segment was identified as a bottleneck and became a red segment on the DSS map. Hourly approach volumes were collected for 16 hours of a typical day so that hourly bottlenecks were identified once capacities for each of the hours were computed.

While developing the DSS, researchers found that ArcGIS software and maps provided the necessary backdrop for the GUI. Programs connect the GUI with the Oracle Database and provided a form interface through which users input changes to traffic and geometric data variables as well as changes in plaza lane configurations. Recalculated capacities are then compared to the newly input traffic volumes to identify and place the new bottlenecks and their locations on the maps. This assists operators in their hour-to-hour decisions concerning the lane configurations at the plaza.

Research Products

This research has developed two very different hybrid models for traffic at toll collection facilities, SHAKER and TNCC, which were both implemented in Java programs to predict NQMT. They also can be used to understand how throughput and other performance measures are dependent upon the characteristics of the approaching traffic to the plaza, upon the lane configuration of the plaza, and upon the properties of the traffic categories such as processing rates for the different categories.
Both models were calibrated with actual data on a network of toll roads maintained by OOCEA. Both models were made accessible by a login onto a DSS website; however, the DSS only integrates TNCC with hourly maps of the OOCEA network of toll roads. The s have been subdivided

Research Benefits

This study demonstrated that tools can be devised to assist engineers and operators to make decisions concerning a network of toll roads, although application for FDOT is dependent upon future efforts (e.g., applying to the Turnpike, plugging in real-time data). Connecting the DSS Oracle database to a real-time data collection database would provide online operators with tools to assist with both hourly and daily decision-making. Using these tools, highway operators would be able to (1) plan for special scheduled events which are known to generate surges in traffic volume, (2) determine the effects of an incident, evacuations (e.g., hurricane), or other unscheduled lane closings, and (3) schedule maintenance and construction-related lane closures during the times of the day when bottlenecks are minimal. Also, engineers could use the tools to (1) design lane configurations at toll facilities, (2) design new interchange locations and predict the consequent effect on toll plazas segments, and (3) predict the effect of adding additional lanes to busy highway segments. Thus, these tools would provide a benefit/cost capability for design purposes and would maximize the ability to manage lane configuration (e.g., altering configuration through the use of dynamic message signs or respond to changes in traffic conditions).

Case Study 15
Central Florida Data Warehouse Phase 2

Project Information

Project Contact
Liang Hsia
(850) 410-5615
liang.hsia@dot.state.fl.us

Principal Investigator
Haitham Al-Deek
haldeek@mail.ucf.edu
(407) 823-2988

Performing Organization
University of Central Florida

Period of Performance
Start: 9/20/2002
Finish: 3/30/2004

Contract Number
BC355-09

Research Needs Statement

The foundation for successfully deploying Intelligent Transportation Systems (ITS) rests upon the effective means of (1) collecting traffic data, (2) filtering that data to improve its quality and accuracy, (3) processing the data, and (4) disseminating the resulting information to the end user. ITS technologies deal with a variety of issues, such as travel time, incident clearance time, speed (flow of traffic), and emergency response time. Without good traffic data and data analysis, road users, from daily commuters to emergency responders, must speculate changing traffic conditions.

Consequently, traffic information plays a substantial role in the traveler decision-making process with respect to departure time, mode selection, and route choice. Widespread traffic information is expected to reduce traffic congestion and associated pollution, lower fuel consumption, enhance traffic safety, and improve traffic management. Thus, one of the chief goals of a traffic management center or TMC (a physical location set up to monitor traffic conditions, manage incidents, and coordinate ITS programs) is to deliver up-to-date information on traffic conditions to both current and prospective travelers.

In a previous phase of study, research resulted in the development of a conceptual design of a Florida traffic information data warehouse. The main challenge of this research (Phase Two) was to implement the conceptual plan with appropriate modifications as applicable to Central Florida. The Central Florida Data Warehouse is a prototype that can be used as a model for the rest of the state.

Research Objectives

There were three main objectives in this study:

1. Design and implement the Central Florida Data Warehouse (CFDW).
2. Develop and launch the Central Florida Regional Transportation Operations
3. Consortium's Traffic Information Website, or iFlorida (www.iflorida.org).
4. Maintain and host the website once it is launched.

Research Methodology

This project represents the first year effort of a three year project. During the first year, the following project activities were completed.

- Completion of a primary fiber connection from the UCF Data Warehouse to the Regional TMC through the Orange County and Orlando-Orange County Expressway Authority fiber network. This connection was used to transmit live video to UCF.
- Development of a new loop detector data-cleaning and filtering algorithm.
- Maintenance of the iFlorida traffic information website for the Central Florida Regional Transportation Operations Consortium.
- Implementation of a 16 camera video system collecting data on I-4 and SR 528.

Research Products

This report documents the management effort and the steps taken towards completion of the first year of a three-year effort to deploy the traffic information data warehouse in Central Florida. Hardware and software components of the CFDW planned for the first year were completed and demonstrated to be functional online.

This large-scale Transportation and Community and System Preservation (TCSP) project can be divided into a number of smaller projects that were successfully completed in this first year. These include the primary fiber connection on the University of Central Florida (UCF) campus project, the data grinding project, the web user interface (UI) design project, the video design project, and the Geographic Information Systems (GIS) integration project. The primary fiber connection was laid out from the entrance of the University of Central Florida at Alafaya Trail along old Central Florida Blvd. to the Multilingual Multicultural Center, which connects through express fiber to the UCF Computer Science building, where the data warehouse servers resided. The primary fiber link was used to transmit live video from the I-4 cameras to UCF. The UCF research team invented a new loop detector data-cleaning and filtering algorithm capable of imputing the data to fill in the holes for missing or incomplete loop detector data.

Before loop data can be used to derive useful traffic information that will be disseminated to the traveling public, this first step must be completed. The data grinding project cleaned the loop detector data and imputed missing data at the five-minute aggregate level. The new algorithm for loop data imputation was developed and successfully implemented online. The web UI project produced the Central Florida Regional Transportation Operations Consortium's Traffic Information Website (or iFlorida, www.iflorida.org), which was launched to the public in late October 2003 and maintained by UCF through February 2004. A “Website User Requirements Document” written by UCF and approved by FDOT District 5 and the Consortium was used to create the website. The web front-end was integrated with the Geographical Information Systems (GIS) software (procured from ESRI or Environmental Systems Research Institute, Inc.) to ensure the functionality of the iFlorida website.

A video project was successfully implemented with 16 cameras that broadcast video snapshots on the website and refresh every 20 seconds. Fifteen of these cameras are located along I-4, and the sixteenth camera is located at the interchange of I-95 and SR 528 in Brevard County. Finally, the CFDW successfully provided web-based, real-time, and predictive travel-time information to commuters and tourists in Central Florida and beyond.

Research Benefits

This project demonstrated the feasibility of advance-information management applications in traffic operations data collection. If the results are expanded, the project has the potential to improve Florida’s traffic operations management capabilities.

The iFlorida website and the Central Florida Data Warehouse (CFDW) can be expanded to include arterials and toll roads in Central Florida. Once expanded and implemented at full scale, they will provide the one-stop shop for traffic information in Central Florida. The expected benefits include reduction in traffic congestion, pollution, and fuel consumption, as well as improvements to traffic safety and traffic management.

Case Study 16
Quantifying the Business Benefits of TDM

Project Information

Project Contact Elizabeth Stutts (850) 414-4350 elizabeth.stutts@dot.state.fl.us	***Principal Investigator*** Philip L. Winters http://www.nctr.usf.edu
Performing Organization University of South Florida Center for Urban Transportation Research 4202 E. Fowler Avenue, CUT 100 Tampa, Florida 33620-3120	***Period of Performance*** Start: 12/20/2000 Finish: 6/30/2002
Contract Amount $30,000.00	***Categorization*** Public Transportation
Contract Number BC137-32	

Research Need Statement

Transportation Demand Management (TDM) is a set of strategies that foster increased efficiency of the transportation system by influencing travel behavior by mode, time, frequency, trip length, cost, and/or route. Many TDM strategies encourage the use of alternatives to single occupancy vehicles (SOV) to reduce congestion and air pollution. These alternatives range from flexible work times and telecommuting to the various available alternatives to SOVs, such as vanpooling and bus service. While the strategies can be applied in a variety of ways, the most effective applications will target approaches that have the greatest impact on mitigating peak hour traffic. Consequently, the effectiveness of such efforts depends largely on the cooperation of local employers and the implementation of organizational policies that support these strategies. That is, employees are more likely to use transit or other TDM strategies if their workplaces have policies that are compatible with them, such as flextime with transit schedules.

The TDM industry, which includes both organizations that advocate TDM (e.g., commuter assistance services) and those that provide transportation services, must largely depend on the empirical evidence of the TDM strategies implemented by employers. The adoption of TDM by employers depends largely on the benefits available to them, which may range from accommodating limited parking facilities to providing employee benefits and increasing productivity. Most of the tool sets available to assess the impacts of TDM programs, however, have focused on transportation and air quality benefits. These public benefits may have little relevance to most employers unless they were subject to a trip reduction mandate (e.g., in an air quality non-attainment area and subjected to EPA mandates). Ironically, TDM programs target employers to carry out their missions. Therefore, evidence of the quantitative benefits that businesses can directly accrue from a wide range of TDM programs could motivate employers to begin, continue, and/or expand travel alternatives.

Research Objectives

The purpose of this research project is to access past research on and current practices in quantifying the business benefits of public transportation and TDM. Researchers will use this information to assemble the various tools used to measure business benefits, which can then be used to promote TDM and increase the adoption of TDM practices, especially in urban areas suffering the effects of congestion.

Research Methodology

Similarities exist between measuring the business benefits of TDM and assessing the impacts of work/life interventions to address the changing needs of the workforce. There are four main approaches to measuring the value of work/life support programs:

- The human-cost approach highlights the reduced labor costs associated with specific interventions.
- The human-investment approach emphasizes the long-term payoffs associated with specific interventions.
- The stakeholder approach identifies benefits that accrue to important organizational stakeholders, such as shareholders, employees, and customers, as a result of specific work/life interventions.
- The strategy approach demonstrates how work/life supports reinforce broad business strategies, such as globalization or providing superior customer service.

These approaches can be helpful in determining the business benefits of TDM.

While there are a variety of methods and tools for estimating the impacts of TDM on vehicle trips and emissions, there is no standardized approach for measuring business benefits in an acceptably rigorous manner. In this study, researchers investigated four business benefits:

- Cost reduction related to turnover. Cost reduction related to absenteeism.
- Parking cost reduction. Employer-provided commuter benefits.

Researchers have provided detailed methods for calculating the cost of savings, to which the human-cost approach (a work/life intervention) is applied. This approach examines the rates and costs before the intervention is offered and compares those rates to rates measured after the intervention is provided.

Research Products

The research recommends the following:

1. Increase public sector research and technical assistance efforts to evaluate employer TDM programs and their impacts on business, as well as transportation and emission.
2. Expand the tracking of employer-provided commute benefits by the Bureau of Labor Statistics to include parking.
3. Integrate, update, and aggressively distribute the tools to estimate the impacts and costs/benefits of TDM businesses.

Research Benefits

This project identifies the key business benefits of TDM and provides techniques for quantifying those benefits. This information should enhance the transportation profession's understanding of the value of TDM to business. An increase in awareness, in turn, should allow agencies to improve levels of employer participation in TDM and other transportation programs, thus reducing congestion and air pollution in Florida.

Case Study 17
Proof of Concept for Simulation Based Re-Certification of Commercial Drivers License

Project Information

Project Manager David Binder (850) 245-7900 david.binder@dot.state.fl.us	***Principal Investigator*** Ron Tarr rtarr@ist.ucf.edu (407) 822-1326
Performing Organization University of Central Florida 12443 Research Parkway, Suite 207 Orlando, FL 32826	***Period of Performance*** Start: 7/30/2003 Finish: 10/31/2004
Contract Amount $ 98,261.54	***Categorization*** Motor Carrier Compliance
Contract Number BC137-32	

Research Needs Statement

The severity of accidents involving commercial vehicles, along with potential terrorist threats involving commercial vehicles, rising fuel costs, and tight budgets all demand that today's drivers operate at their highest possible performance levels. The FDOT and the U.S. Department of Transportation have identified operator performance and safety as major objectives in addressing these intermodal transportation needs of the state and the nation. Among the most significant issues identified in this area are the challenge of commercial driver license (CDL) re-certification and the development of a cost-effective method of identifying fraudulent CDLs, issued either through illegal means or as a result of inadequate training. This situation includes those who have been grandfathered into the 1992 CDL program from the previous program without any actual driver performance assessment. Currently, no performance based re-certification process exists to ensure the capability of the driving workforce or to provide diagnosis of potential problems, either from lack of experience or improper training.

Research Objectives

The overall goal of this research was to explore and validate the application of computer-based and simulation-based technologies to the commercial driving community. The objective was to validate a newly developed virtual diagnostic test application (i.e., the Virtual Check Ride System or VCRS) that provides a valid, low-cost process for determining drivers' skills and commercial vehicle knowledge. Research and development processes include various simulators and learning technologies to improve driver/operator safety and performance in the trucking and transportation communities.

Research Methodology

In conducting the study that resulted in VCRS and its subsequent validation, several considerations were determined to be critical: mirroring the United States Federal Regulation; understanding the issues of the trucking community and what it considered critical success measures; a robust sample size; and a primary focus on driver performance with the technology being clearly a means to that end. The following tasks were laid out to accomplish the research and validation of the VCR:

Task 1: Review and analyze the federal and state directives and existing processes for the current CDL test and for establishing criteria and measures of success for proper performance measurement. Armed with the current specified driver performance requirements for the CDL, the research team looked for alternative techniques that could achieve the measurement needs in a minimal amount of time. Efforts included assessment, verification, and examination of current operational or "live" systems, training systems, simulation systems, prototype systems, and any technology transfer initiatives.

Task 2: Under two previously related efforts, information on certification methods using simulation and a demonstration proof of concept for the prototype of a VCR were developed. The proof of concept package, similar to the traditional CDL test, consisted of a knowledge test and a pre-trip virtual inspection of a vehicle, followed by a simulated drive using the L3 I-Sim located at CATSS. This demonstration material was reviewed by several Subject Matter Experts (SMEs) from the transportation community, who had operational driving experience and who were certified CDL examiners. The results of this Proof of Concept were used as input for the next generation application. These elements were expanded into the operational version, based on implementation of the completed regulatory review, SME feedback gathered from the demo version, and by formal expansion and establishment of an item bank of validated CDL knowledge test items. In addition, a formal set of CDL Driving Skills scenarios was developed based on the Florida CDL Examiner's manual. The results of all these efforts were examined and integrated into the development of the operational beta version along with necessary implementation procedures that include the After Action Review (AAR) process for the feedback session of the program.

Task 3: Validation of Prototype. In conjunction with industry partners, such as Roadmaster Driving School and Florida Trucking Association representatives, the formal process of validation was conducted using both the fixed facility at CATSS and a portable component network set operated by the CATSS study team and trained members of the sponsoring organizations. This validation used a quasi-experimental design with the model developed previously under research sponsored by CATSS, (Tarr, Development and Integration of Certification Standards for Transportation Training Simulation Systems, 2002) as well as reviewed for content and implementation by selected SMEs who are qualified CDL examiners. Feedback and evaluation data was collected routinely to ensure the quality and appropriateness of the training and to measure performance enhancements. Electronic records of the Virtual Check Ride were built into the prototype network, both for validation to document the success of the interventions and also for use as the basis for future research and to be used for AAR in the operational system.

Research Products

The VCRS was found to offer a valid assessment of the skills required to pass the current CDL test (future research will look into the use of the VCRS as both a recertification test for the CDL and as a diagnostic tool for the trucking community). There were two main areas of testing that researchers investigated: simulation and computer-based training (CBT). The simulation portion of the exam follows the CDL driving test by using a truck driving simulator to replicate the actual CDL process. The CBT portion of the experiment measures the knowledge base of the drivers in a variety of areas: general knowledge, combination vehicles, hazardous materials, air-breaks, and the conduct and content of a walk around inspection. The goal of having the CDL test in computer-based format is to establish a cost-effective way to facilitate the re-certification process.

Content testing related to the knowledge and skills necessary for safe driving was validated using 200 subjects from six different organizations along with samplings from various truck driving communities. Some of the key participants were Frito Lay, CCC, Schenk, and Roadmaster (a certified private truck driving school). Roadmaster provided certified CDL school trained and CDL-licensed subjects, including drivers, instructors, and subject matter experts.

Benefits

The primary benefit of this research is that it formally demonstrates and documents the potential utility of computer-based simulation for CDL recertification and as a cost-effective method for identifying fraudulent CDLs. Given current testing and certification costs in manpower, vehicles, space, scheduling, and fuel, the ability to conduct a valid CDL test in two hours, under any weather conditions, and on-site (i.e., at the truck depot) could provide enormous cost savings over the much more labor- and facility-intensive existing process. The savings in reduction of crashes and injuries cannot be estimated at this time; however, providing a tool such as the VCR could identify potential problem drivers before incidents occur and be a major contributor to achieving the State and Federal goal of 40% reduction over the next five years

Case Study 18
Improving Operation of FDOT Telemetered Traffic Monitoring Site

Project Information

Project Manager
Harshad Desai
(850) 414-4718
harshad.desai@dot.state.fl.us

Principal Investigator
Bruce A. Harvey
(850) 410-6451
bharvey@eng.fsu.edu

Performing Organization
FAMU-FSU College of Engineering
Florida State University
2525 Pottsdamer Street
Tallahassee, FL, 32310-6046

Period of Performance
Start: 4/12/2000
Finish: 9/30/2002

Contract Amount
$259,740.00

Categorization
Planning

Contract Number
BC596

Research Need Statement

The Florida Department of Transportation (FDOT) currently monitors about 7,000 traffic count sites, including over 300 permanent Telemetered Traffic Monitoring Sites (TTMS). The monitoring equipment generally consists of traffic-actuated sensing devices embedded in the pavement that capture traffic volumes, vehicle classifications, and truck weights. The data gathered is then downloaded and processed for Annual Average Daily Traffic (ATD), K-factor, T-factor, truck weight, and other pertinent information. This information is used in various forms by different FDOT offices for planning, design, operations, and maintenance activities relating to both highway pavements and bridges. Cellular technology can reduce the amount time and labor required to download data in the field. However, problems exist with the accuracy and reliability of the communication equipment, as well as with the TTMS sensors.

Research Objectives

The primary objectives of this study involved the following:

- The improvement of cellular communication for site 9936.
- A study of modem performance.
- The implementation of telephone line surge protection.

- An evaluation of the bonding materials used in piezoelectric axle sensor installation.
- The mining of Florida ITS data for transportation planning purposes.

Research Methodology

Different activities were performed for each task:

A review of all commercial cellular and PCS communication providers in the area of site 9936 was conducted. A literature search was also conducted to determine the performance pitfalls of cellular data communication and to identify the equipment settings required to optimize performance. Wireless communication characteristics were studied, including the service area boundaries of cellular towers defined by the Code of Federal Regulations (CFR), Chapter 47 Part 22.

A Teltone TLE-A01 telephone line emulator was acquired to test the compatibility and performance of various pairs of modems. A total of eight DC modem types and four desktop modem types were acquired for testing in this phase of the project. Using the TLE-A01, pairs of modems were evaluated in the presence of ideal line conditions, signal attenuation, noise and a combination of impairments.
During the initial phase of this task, failed surge suppressors were examined and tested to determine the mode of failure. To further quantify the lightning surge environment, hand-held data logging meters were installed in a few TTMS sites. These meters were able to log the time and peak voltage of surges entering through the telephone lines.

For the second phase, a surge generator was acquired to determine the suppressors' resistance to failure. The generator was capable of generating current surges up to 6000 Amps. Testing was performed on surge suppressors acquired or borrowed from EDCO, Citel, and Surge Suppression, Inc. Also, a surge protector designed specifically for the FDOT by Thomlinson Instruments and Controls, Inc. was tested.

A research protocol was designed to evaluate the performance of piezos so as to recommend which adhesives would be suitable for Florida conditions. The protocol included (a) a comprehensive literature search on the characteristics of epoxies, acrylics, and polyurethanes, (b) a survey of the experiences of state transportation departments in the U.S. on the use of these adhesives for piezo installations, (c) laboratory testing of the approved adhesives, and (d) long-term field monitoring of ANOVA-designed experiments.

Four activities were conducted during this task: (a) a comprehensive literature search of both published and unpublished information was conducted to determine similar efforts in other states and other countries; (b) a computer resident at the University of Central Florida (UCF) in the Orlando Regional Traffic Management Center (RTMC) control room downloaded the detector log file and video images with a computer program and the data captured by this computer was transmitted to a UCF laboratory where its configuration was studied; (c) a computer was installed in Orlando to capture the detector log file for mining of the ITS data; and (d) a computer program was written and installed on the FAMU- FSU computer to gather the data from the detector log file. The program file name is ReaderByChar.java and was written in Java programming language.

Research Products

The following research products were developed:

- The communications reliability with the cellular modem at site 9936 was improved. Recommendations for cellular site installations address the use and proper installation of high-gain directional antennas to improve power, as well as the use of a flow-loss cable between the antenna and the cellular transceiver. Also, the best cellular provider was identified by locating their nearest tower and obtaining assistance in aiming the directional cellular antenna.
- Recommended modem specifications and test procedures were developed to determine the causes of poor performance and apparent incompatibilities between certain modems.
- Researchers identified current surges as the primary cause of suppressor failures as opposed to a high-current direct lightning strike. Recommended telephone line surge suppressor specifications and test procedures were developed.
- Recommended acrylic-based adhesives were identified, and additional testing of one particular epoxy-based adhesive was recommended in order to develop material specifications for selecting adhesives to achieve long-term field performance of piezolelectric axle sensors suitable for Florida traffic, pavement, and environmental conditions.
- The pilot project study on site 750196 at station 36 on the I-4 corridor in Orlando showed that it is possible to extract planning-compatible traffic data from loops installed on freeways, for incident surveillance and other ITS purposes.

Research Benefits

There were several benefits of this research. First, a host of improvements to communications setups were made, both to particular site operations and to specifications. Alternative adhesives with the potential to increase the long-term performance of piezoelectric axle sensors were identified. The processes and mechanisms for capturing and converting ITS data were developed and tested. The FDOT District V Planning Office is currently able to download traffic data composed of hourly volumes from several sites along the I-4 corridor. Furthermore, as a result of this study, FDOT may save $200,000 by foregoing the installation of new loops for collecting planning data in areas where ATMS loops already exist on I-4. Additional sites will be incorporated into the expansion of ITS activities along the I-4 corridor, thus reducing the need to install TTMS sites along the corridor and resulting in additional savings.

Case Study 19
Application of Fiber-Reinforced Concrete in the End Zones of Precast, Prestressed Bridge Girders

Project Information

Project Manager
Dongzhou Huang
(850) 414-4660
dongzhou.huang@dot.state.fl.us

Principal Investigator
Nur Yazdanu
(850) 410-6125
yazdani@eng.fsu.edu

Performing Organization
Florida A&M University – Florida State University College of Engineering

Period of Performance
Start: 9/20/1999
Finish: 2/15/2002

Contract Amount
$118,361.00

Categorization
Structures

Contract Number
BC386

Research Need Statement

Prestressed concrete is a widely used material for bridge construction. Compared to its compressive strength, the tensile strength of reinforced concrete is limited. Consequently, prestressing becomes essential in many applications to fully utilize the compressive strength and, through proper design, to eliminate or control cracking and deflection. Technological advancements in the science of materials have made it possible to construct and assemble large-span prestressed concrete systems.

Precast post-tensioned girders are subjected to high concentrations of compressive stresses at the anchorage zone due to the transfer of prestressing force at the girder end through bearing plates and anchors. Most damage to anchorage zones in post-tensioned concrete structures occurs during construction, when large tendon-stressing forces are applied to usually immature concrete. A considerable amount of spiral and skin reinforcement is required at the end zones of a prestressed bridge girder. Reinforcement congestion in the anchorage zone is a frequent cause for poor concrete consolidation, which results in failures created by the crushing of concrete ahead of the anchor. Congested anchorage zone details also complicate the placement of the reinforcement. Various reinforcement components used in close proximity cause congestion in the anchorage zone, which makes the placement of concrete, anchorages, and post-tensioning ducts difficult. Furthermore, producing and placing the secondary anchorage reinforcement is labor intensive.

Fiber-reinforced concrete (FRC) possesses better properties, such as tension strength, compression strength, shear strength, bond strength, flexural toughness, and ductility, than conventional concrete. Therefore, it may be possible to utilize FRC in the end zones of prestressed bridge girders to reduce the amount of secondary reinforcement.

Research Objectives

The principal goal of this study was to investigate, theoretically and experimentally, the application of FRC for the aforementioned purpose of improving reinforcement options for prestressed concrete members. Specific objectives include the following:

- To establish various properties of FRC relevant to bridge design.
- To select adequate synthetic or steel fibers for application in anchorage zones.
- To experimentally determine the feasibility of reducing or eliminating the secondary reinforcement through the use of synthetic or steel fibers in post-tensioned anchorage zones.
- To perform theoretical validation of the feasibility of FRC application in anchorage zones.
- To make a cost comparison between fiber-reinforced and conventionally constructed girders, based on both material and labor costs.

Research Methodology

The study examined the feasibility of using fiber reinforced concrete in the end zones of girders. Researchers first evaluated the mechanical properties of FRC using both synthetic and steel fibers. Properties of concrete without fiber and FRC were then compared to the properties of concrete with FRC. Understanding the various properties of FRC helped in selecting fibers for further evaluation. The AASHTO acceptance test for anchorage zones was subsequently utilized.

In order to analyze the mechanical properties of FRC, three different tests were used, each one with different types and amounts of fibers. These tests included the Compressive Strength Test, the Split Tensile Strength Test, and the Flexural Toughness Test. All tests were performed as per ASTM standards: ASTM C-39, ASTM C-496, and ASTM C-1018, respectively.

The Compressive Strength Test was performed using a 55 kip Forney Universal Machine at the FAMU-FSU College of Engineering. The machine has a steel platen base and a steel loading platen. The compressive force was applied to the cylinder through the bottom platen. The failure load was obtained from the digitally recorded reading of the machine. The Split Tensile Strength was performed using the Forney Universal Testing Machine at the FAMU-FSU College of Engineering following a procedure similar to the first test. The Flexural Toughness Test was performed using a 50 kip servo-controlled electro-hydraulic, closed loop Material Testing System (MTS) at the FAMU-FSU College of Engineering. The load reading was obtained manually from the MTS machine.

Three test procedures are specified by AASHTO (1998) for the evaluation of local anchorage zone reinforcement: the Cyclic Loading Test, the Sustained Loading Test, and the Monotonic Loading Test. For the purposes of this study, the Cyclic Loading Test was preferred. This testing effort was carried out at the Structures Research Laboratory. The finite element models were used to better understand the time, origin, and location of cracks in the specimens, as well as the strain evolution during different loadings.

Research Products

The first phase of the test program involved the determination of the split tensile strength, the compressive strength, and the flexural toughness of FRC and non-fibrous concrete. Two steel fibers and one synthetic fiber with volumetric dosage rates of 0.75% and 1.0% were utilized. Steel fibers enhanced the properties of concrete, but the synthetic fiber proved less useful. In the second phase, the AASHTO Special Anchorage Device Acceptance Test was performed. Variations of spiral and skin reinforcement, with two levels of concrete strengths, were utilized to investigate the performance of the two types and various volumetric percentage amounts of steel fibers. The experimental results indicated that 1% steel fiber could be used to replace all the secondary reinforcement for a minimum concrete strength of 5900 psi (40.7 MPa), and that it could reduce a maximum of 79% of the secondary reinforcement for a minimum concrete strength of 4710 psi (32.5 MPa). Lower volumes of steel fibers may also result in a reduction of secondary reinforcements.

A finite element model of the AASHTO test block was also developed to validate the experimental results. Researchers found the theoretical and experimental strain values to be in agreement. Usage of steel fiber reinforced concrete in the anchorage zones will result in negligible change in the girder costs.

The product of this study, distributed as a research report, is new knowledge concerning the application of Fiber Reinforcement in Prestressed Concrete. This knowledge will permit designers to produce more efficient designs with resulting cost savings.

Research Benefits

This research demonstrated the feasibility of substituting or reducing the secondary reinforcement, such as spiral reinforcement and skin reinforcement, in the anchorage zones of precast post-tensioned bridge girders. The tests and analysis showed that the secondary reinforcement could be completely eliminated through the use of 1% steel fiber in the anchorage zone. A secondary reinforcement is hard to fabricate and place, and it can cause substantial local steel congestion, which leads to difficulty in concrete placement and inferior concrete quality. This problem, in turn, may lead to premature concrete cracking and long-term durability issues. The utilization of steel fibers in the anchorage zone is convenient, and it can be achieved with negligible extra material and labor costs. Thus, this practice is expected to result in strong and durable concrete anchorage zones, as well as substantial economic savings.

Case Study 20
Capacity of the OOCEA Network of Toll with ETC

Project Information

Project Coordinator
Liang Hsia
(850) 410-5615
liang.hsia@dot.state.fl.us

Principal Investigator
Essam Radwan
(407) 823-4738
(407) 823-3315 (fax)
aeradwan@mail.ucf.edu

Performing Organization
Department of Civil and Environmental Engineering
Center for Advanced Traffic Systems Simulation
University of Central Florida

Period of Performance
Start: 6/25/2001
Finish: 12/31/2002

Contract Amount
$40,079.00

Categorization
Traffic Operations

Contract Number
BC096-15

Research Need Statement

The efficiency of traffic management at toll facilities is based on a host of variables that determine a facility's capacity. The bottlenecking of traffic, for example, may occur when a less-than-optimal configuration is employed. Toll plaza characteristics such as the number of lanes, the customer-group configuration, and processing rates have to be weighed alongside traffic characteristics like vehicle type and percent distribution to determine facility capacity. Mathematically, the process of manipulating these variables can be tedious and often redundant. The Toll Network Capacity Calculator (TNCC) is a software package that streamlines the capacity calculation process, making comparative data available to analyze a toll facility's efficiency and ability to adjust to different input traffic characteristics.

Research Objectives

The primary objective of this research project was to quantify the capacity of the OOCEA network of highways (Orlando Orange County Expressway Authority). The capacity of the network includes combined capacities of the toll roads and all the toll collection facilities in the network. A secondary objective was to determine the reliability of the TNCC methodology (Toll Network Capacity Calculations). The three primary tasks of this study included the following:

- To incorporate the TNCC methodology into a simple Visual Basic Program that automates the calculations for the capacity of individual toll facilities.
- To test a new capacities-calculating methodology by applying it to highway sections containing toll plazas.
- To quantify the capacity of consecutive highway sections on the OOCEA network of toll roads, thus identifying bottlenecks.

Research Methodology

Capacities, in passenger cars per hour (pcph), are converted to service flows, in vehicles per hour (vph). This allows for a comparison analysis to volume values, also in vph. If a highway segment's approaching traffic volume is larger than the segment's service flow, then a bottleneck is identified.

Calculated capacities, in pcph, and service flows, in vph, are based on traffic and roadway conditions from August 16, 2000. Plaza lane configurations are also taken from lane patterns on this day. Traffic volumes leaving the plazas are also taken from transaction data at the plazas from 7 a.m. to 8 a.m. on August 16, 2000 provided by the OOCEA. However, volumes of highway segments between the plazas are from 2001 traffic volumes between the times of 7:00 a.m. to 8:00 p.m., and are extracted from tables provided by Post, Buckley, Schuh and Jernigan, Inc., PBS&J. Most of the volumes for each of the 295 highway segments are from 7:00 a.m. to 8:00 a.m.

It should be noted that the bottlenecks identified in this analysis are only for morning commuter traffic. For evening commuter traffic, a new analysis would produce a different set of bottlenecks and bottleneck locations, and the research outlined in this study could be used as a foundation to easily identify evening commuter traffic bottlenecks. The analysis of sixteen consecutive hours would result in bottleneck location shifts during the day from 6:00 a.m. to 10:00 p.m. A time simulation of these sixteen hours could graphically illustrate bottleneck location shifts on the network map during a typical day.

Research Product

The network was divided into 295 highway segments, 20 of which contain a toll facility, and the capacities and service flow rates for 38 on-ramp and off-ramp toll facilities were calculated. The Highway Capacity Manual (2000) provided the methodology for computing most of the highway segment capacities. However, a methodology had to be designed to compute the capacities and maximum service flow rates of the 20 segments containing a toll facility. The traffic using the network was broken into four categories: 1) vehicles using the Electronic Toll Collection (ETC) service, 2) vehicles using the Automatic Coin Machine (ACM) service, 3) vehicles other than semi-trucks using the Manual Service, and 4) semi-trucks using the Manual Service. The network was videotaped during the morning peak rush hours, and the resulting data was used as input in TNCC's capacity calculations.

The analysis led to the identification of bottlenecks, near bottleneck situations, and potential bottleneck situations. Also, a sensitivity analysis was conducted on each input variable used in TNCC. All but one of the input variables entered into TNCC remained constant, indicating that TNCC predicts capacities and maximum service flow rates in an expected and reasonable fashion for simple plaza lane configurations. However, TNCC could also mimic more complex plaza performance characteristics, such as the overflow movement of vehicles shifting from dedicated ETC lanes to lanes providing mixed services.

Research Benefits

There is a strong preliminary indication that the TNCC methodology for calculating the capacity of toll facilities is both reliable and useful. Whenever lanes must be closed at toll collection facilities due to maintenance or incidents, a disruption in traffic flow occurs as a result of a reduction in capacity. Thus, TNCC may assist in disruption management. It may determine the impact of a lane closure and help operators adjust the remaining lane configuration to help alleviate the disruption(e.g., TNCC may suggest opening up the remaining lanes to other services). Traffic characteristics, such as the percent of ETC usage, manual usage, and ACM usage, serve as inputs in TNCC for using a new lane configuration.

Appendix B Inventory of FDOT Cost and Planning Data Resources

Title of Report or Document:

Average Unit Cost

Location and Publisher:
FDOT
State Estimates Office
http://www.dot.state.fl.us/estimates/TRNSPORT/PayItems.htm#ItemAverageUnitCost

Description of Data:

Quantity weighted average unit cost for construction pay items.
State wide averages and averages for different regions are provided.
Quantity of the item paid for and installed is also provided.

Application and Uses:

Establish current and past unit cost for individual construction items.
Establish current and past state wide quantities for individual construction items.

Note: Use search feature available in the pdf file to find desired pay item.

Sample Data:

CESPO05 11/09/2004-09.44.04 Page: 3

Florida Department of Transportation
Item Average Unit Cost
From 2002/01/01 to 2004/10/31

Contract Type: ALL STATEWIDE
Displaying: VALID ITEMS WITH HITS
From: 0050 To: 1999999999

Item	No. of Conts	Weighted Average	Total Amount	Total Quantity	Unit Meas	Obs?	Description
0102912 2	96	$1.20	$1,172,682.78	974,420.000	LF	N	PAVT MARKING REMOVABLE (YELLOW) (SOLID)
0102912 3	11	$3.11	$13,903.10	4,475.000	SF	N	PAVT MARKING REMOVABLE (YELLOW) (OTHER)
0103 1	2	$1,200,000.00	$3,600,000.00	3.000	LS	N	TEMPORARY WORK STRUCTURE
0104 1	91	$1.63	$347,228.23	213,250.600	SY	N	ARTIFICIAL COVERINGS
0104 4	212	$80.44	$1,840,723.64	22,883.419	AC	N	MOWING
0104 5	43	$70.72	$347,711.21	4,916.700	CY	N	SANDBAGGING
0104 6	24	$16.34	$233,340.20	14,280.000	LF	N	SLOPE DRAINS (TEMPORARY)
0104 7	6	$1,196.78	$153,187.80	128.000	EA	N	SEDIMENT BASINS
0104 9	6	$2,271.67	$304,403.88	134.000	CO	N	SEDIMENT BASIN CLEANOUTS

Title of Report or Document:

Five Year Work Resource and Program Plan Summary

Location and Publisher:

FDOT
Office of Financial Development
http://www.dot.state.fl.us/financialplanning/

Description of Data:

Provides projected cost allocation data for the FDOT work program for a total of 10 years.
Cost totals are provided for different categories of cost such as design or construction. Cost totals are also given for different project types such as bridges or resurfacing.

Application and Uses:

Comparison of past funding amounts to planned future funding amounts can be used to estimate future quantities of design and/or construction work items.

Sample Data:

06TENT07.xls
06TENT07
WORK PROGRAM
FILE: 8-March-2005
(Excludes Hurricanes C6-C9)

FLORIDA DEPARTMENT OF TRANSPORTATION
2004/05 PROGRAM AND RESOURCE PLAN SUMMARY
FISCAL YEARS 2005/06 TO 2013/14
(MILLIONS OF $)

OFD
9-Mar-2005
1:45 PM

ALL BUT TURNPIKE	ACTUAL	PLAN	First Five Years						Next Four Years					10 YR.
PROGRAM AREAS	03/04	04/05	05/06	06/07	07/08	08/09	09/10	TOTAL	10/11	11/12	12/13	13/14	TOTAL	TOTAL
I. PRODUCT	3386.3	5587.2	3977.9	3022.1	3318.1	3113.7	3509.6	**16941.3**	3229.1	3284.6	3563.6	3287.4	13364.7	**35893.2**
A. SIS/Intrastate Highways	1025.4	1097.8	1072.3	485.4	946.5	748.2	930.1	4182.5	992.0	993.1	1230.4	1138.6	4354.2	9634.5
B. Other Arterials	540.6	972.8	767.5	624.2	677.0	684.3	631.5	3384.6	547.4	513.4	506.1	449.9	2016.8	6374.1
C. Right Of Way	376.2	1333.0	494.2	338.6	364.7	307.0	512.3	2016.8	319.2	373.7	390.9	227.7	1311.5	4661.4
D. Aviation	107.0	152.7	115.7	100.2	106.7	107.4	129.3	559.3	115.1	118.5	122.1	126.2	481.8	1193.9
E. Transit	171.8	242.5	279.1	210.1	214.6	205.2	224.1	1133.1	221.9	230.4	233.4	240.6	926.3	2301.9
F. Rail	43.8	67.1	163.5	125.4	93.1	119.5	130.9	632.3	114.4	117.6	120.8	119.7	472.5	1172.0
G. Intermodal Access	208.8	387.6	150.2	224.7	37.1	49.1	62.2	523.3	51.4	52.9	54.5	56.2	215.0	1125.9
H. Seaports	34.4	52.6	53.2	40.0	48.4	40.0	51.7	233.3	40.0	40.0	40.0	40.0	160.0	445.9
I. Safety	64.7	131.6	106.1	56.3	51.9	56.0	61.0	331.4	64.6	66.6	68.6	70.3	270.1	733.1
J. Resurfacing	489.5	701.9	641.7	657.5	665.2	600.6	609.9	3175.0	612.6	622.3	637.3	653.9	2526.1	6403.0
K. Bridge	324.2	447.5	134.2	159.6	113.0	196.4	166.6	769.8	150.4	156.1	159.6	164.2	630.3	1847.6
L. Trans. Outreach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
II. PRODUCT SUPPORT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Title of Report or Document:

2004 Transportation Costs

Location and Publisher:
FDOT
Office of Policy Planning
http://www.dot.state.fl.us/planning/policy/default.htm

Description of Data:

Provides average unit cost for completed transportation system components.
For example: average cost per lane mile for highways
Average cost per SF for bridges

Also, provides a Florida Consumer and Construction Cost Inflation Indices.

Application and Uses:

Average cost can be used to estimate total cost of project components.

Cost Inflation Indices can be used to adjust estimated future cost for inflation.

Sample Data:

Bridge Costs
2004

New Construction
(Cost per Square Foot)

Bridge Type	Low	High
Short Span Bridges		
Reinforced Concrete Flat Slab Simple Span	$70	$90
Pre-cast Concrete Slab Simple Span	$115	$168
Reinforced Concrete Flat Slab Continuous Span	NA	NA
Medium Span Bridges		
Concrete Deck/ Steel Girder - Simple Span	$85	$110
Concrete Deck/ Steel Girder - Continuous Span	$95	$160
Concrete Deck/ Pre-stressed Girder - Simple Span	$70	$110
Concrete Deck/ Pre-stressed Girder - Continuous Span	$85	$125

Title of Report or Document:

Trends and Conditions Reports

Location and Publisher:
FDOT
Office of Policy Planning
http://www.dot.state.fl.us/planning/policy/default.htm

Description of Data:

A number of different reports that provide information on traveler user demand levels, safety, population growth and other trends.

Application and Uses:

Information can be used to estimate the effect of system improvements on the traveling public.

Sample Data:

Table 1 – Florida Traffic Crash Statistics, 2000 and 2001

	2000		2001	
Traffic Crashes				
Fatal	2,733		2,717	
Injury	144,096		145,208	
Property Damage Only	99,712		108,244	
Total	246,541		256,169	
Traffic Crash Victims	Killed	Injured	Killed	Injured
Drivers	1,495	144,845	1,449	145,339
Passengers	688	69,869	695	71,790
Pedestrians	506	7,782	510	7,894
Bicyclists	83	4,618	107	4,476
Motorcyclists	227	4,474	252	5,101
Total	2,999	231,588	3,013	234,600

Title of Report or Document:

Florida Traffic Information

Location and Publisher:
FDOT
Office of Traffic Operations
http://www.dot.state.fl.us/trafficoperations/

Description of Data:

Provided as a software package on a CD. Includes traffic statistics and conditions for Florida road system, as well as monitoring and projection procedures.

Application and Uses:

Information can be used to estimate the effect of system improvements on the traveling public, such as reduction in travel time.

Sample Data:

Print Date: April 06, 2004

Florida Department of Transportation
Transportation Statistics Office
Historical AADT Report

County: 74 - NASSAU

Site 0132 SR-9/I-95,2.0 MI S OF GA. STATE LINE,NASSAU CO.

Year	AADT	Direction 1	Direction 2
2002	C 51,792	N 26,031	S 25,761
2001	C 52,258	N 26,485	S 25,773
2000	C 50,135	N 24,957	S 25,178
1999	C 48,713	N 24,451	S 24,262
1998	C 47,505	N 23,822	S 23,683

DRAFT

Title of Report or Document:

Crash Facts 2002

Location and Publisher:

Florida Department of Highway Safety and Motor Vehicles
http://www.hsmv.state.fl.us/hsmvdocs/cf2002.pdf

Description of Data:

Annual report that provides crash data for Florida road systems.

Application and Uses:

Information can be used to estimate the effect of system improvements on the traveling public, such as reduction in accidents.

Sample Data:

TABLE 1C

Comparative Safety Equipment Use By BICYCLISTS AND THEIR PASSENGERS

BICYCLISTS	No Injury	%	Possible Injury	%	Non-Incapacitating Injury	%	Incapacitating Injury	%	Fatal	%	% Total	TOTAL
With Safety Helmet												
Driver	32	6.03	133	25.05	283	53.30	78	14.69	5	0.94	100	531
Passenger	6	75.00	1	12.50	1	12.50	0	0.00	0	0.00	100	8
SUBTOTAL	38		134		284		78		5			539
Without Safety Helmet												
Driver	338	6.91	1,394	28.48	2,267	46.31	793	16.20	103	2.10	100	4,895
Passenger	39	38.24	32	31.37	22	21.57	8	7.84	1	0.98	100	102
SUBTOTAL	377		1,426		2,289		801		104			4,997
TOTAL	**415**		**1,560**		**2,573**		**879**		**109**			**5,536**