KENTRUCKY TRANSPORTATION CENTER

VALUE OF RESEARCH FROM 2000-2005: THE KENTUCKY SPR PROGRAM FOR HIGHWAY RESEARCH

UNIVERSITY OF KENTUCKY
College of Engineering

OUR MISSION

We provide services to the transportation community through research, technology transfer and education. We create and participate in partnerships to promote safe and effective transportation systems.

OUR VALUES

Teamwork
Listening and communicating along with courtesy and respect for others.

Honesty and Ethical Behavior
Delivering the highest quality products and services.

Continuous Improvement
In all that we do.

Value of Research from 2000-2005:
The Kentucky SPR Program for Highway Research

by
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(and others)

Kentucky Transportation Center
College of Engineering
University of Kentucky

in cooperation with the
Kentucky Transportation Cabinet
and
Federal Highway Administration
U.S. Department of Transportation

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16. Abstract

The abstracts of the 79 SPR reports completed by KTC researchers for 2000-2005 were compiled. Seven projects were selected for value review to demonstrate the various types of Benefits that accrue from SPR project research. This review compared objectives with results and described the nature of the benefits (some quantifiable). All of the projects were analyzed to determine: 1) the Kentucky Transportation Cabinet (and FHWA) goals supported and 2) the types of benefits that would reasonably be expected to accrue from implemented results of the research. Most of the 79 projects' results address both improving the performance of the Cabinet and the sustainability (reduction of a variety of intrinsic and extrinsic costs) of the transportation system. The precise value of the research results of the 79 projects is difficult to ascertain. However, the review provides reasonable evidence that substantial value has accrued and will continue to grow as the results continue to be implemented. A definition of applied research along with a discussion of who does transportation research and the challenge of implementation are provided.

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Acknowledgements

The Wall Street Journal and a leading economist at Stanford University along with many others believe that the U.S. simply is not graduating enough scientists and engineers to make the discoveries and solve the problems in the years ahead. Concern is growing nationally about this shortage along with the lessening of expenditures for research and development. This is seen as a real challenge to America's prosperity. Transportation research and development is not immune to this growing deficit of qualified researchers and funding. Transportation research plays a vital part in assuring the future effectiveness and efficiency of our transportation system that is a critical factor in the Commonwealth's future economic development and quality of life. Those who appreciate the role of applied research and are willing to invest in something that contributes beyond today's bottom line are to be commended.

This report would not have been possible without all the applied research project work that was completed and documented in the 2000-2005 timeframe. Eighty project research teams were created along with study advisory committees to achieve this result. Typically, 2-5 researchers with technical and administrative staff support, along with a 5-15 member study advisory committee are involved with each project over a 1 to 2-year timeframe. The most experienced researchers or team leaders are responsible for preparing final project reports and drafting implementation plans. Study advisory committee members provide guidance and oversight in addition to their "day job" at the Kentucky Transportation Cabinet. Special thanks goes to Pat Riggs who maintains the file of research project reports at the center and compiled the appendix listing of projects with abstracts.

Introduction

The purpose of this report is to provide an overview of the past five years of SPR* -- funded highway research, an assessment of benefits and a focused review of several research projects to demonstrate the range of benefits. During this period, 79 applied research projects were completed in nine designated research program areas. Nearly every project resulted in a published report that is available as a PDF file on the center's Web site. This report provides a listing of the completed projects with abstracts for all but a few in the appendix. The total value of the research represented herewith can only be surmised. However, the value continues to grow as findings are understood and the recommendations are implemented. Quantitative benefit substantiation is rather easily done for some specific examples such as the two companion research projects:

1) Flexural Behavior of R/C Beams Strengthened with CRFP and
2) Shear Strength of R/C Beams Wrapped with CRFC. (see pages 34-35)

However, other projects require qualitative or semi-quantitative analysis that is time intensive and costly. Nevertheless, an understanding of the project objectives and a review of the results/recommendations allow a reasonable person to assess the likelihood of accruing benefits if the recommendations were able to be implemented. The nature of the benefits can be determined.

In order to help understand the potential value of the research represented by five years of SPR funding, this report provides a listing of all projects and makes a determination of the specific Cabinet/FHWA goals the project supported and the type of benefits that will reasonably accrue due to the implementation of the findings and recommendations. It must be noted that the completeness and timeliness of the implementation, for the most part, is outside of the purview of the research team. Methods to make applied transportation research more useful have been undertaken during this period. Focus has

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*SPR refers to the federal/state highway funds dedicated to State Planning and Research.

been on selecting high priority research projects working closely with the research client. In addition, efforts have been made to insure that the research results become useful through establishing a plan for implementation at the conclusion of each research project.

Applied transportation research presents several challenges to researchers and clients. Those include: 1) selecting the problem/issue to be addressed; 2) developing a work plan that makes the objectives clear; 3) managing the work to meet milestones on time and on budget; 4) documenting the work and presenting the findings and recommendations; and 5) planning for and implementing the recommendations. Success in meeting each of these challenges impacts the value of the research. In order to properly address some transportation research problems and issues interdisciplinary cooperation is required. The center works with researchers and subject experts in other colleges, other universities and private sector transportation planning, engineering and technology firms. Bringing such diverse views to bear on research problems and issues requires additional leadership and teamwork skills.

During this 5-year period KTC has continued to become nationally recognized and has successfully competed for several NCHRP studies. Special areas of recognition include research, development and training in ITS/CVO (commercial vehicle operations) and CSD/CSS (context sensitive solutions).

Summary of Findings

During the 2000-2005 period of this report 79 projects were completed and documented in written reports. All but three of these reports have been published and all those published, beginning with 2001, are available in PDF form on the center's Web site. Hard copies of all published reports can be requested through the center's library and beginning with 2001, they are also available in CD format. A title listing of the 79 projects' reports, including an indication of the strategic initiatives supported and the benefit types to be anticipated, conclude this summary section. The number of projects in each research program area are: 9-Construction Management; 6-Environmental Analysis; 2-Financial Analysis; 8-Geotechnology; 6-Intelligent Transportation Systems; 8-Pavements and Materials; 8-Planning and Systems Analysis; 7-Structures and Coatings; 25-Traffic and Safety.

A review of the projects' topics for 2000-2005 indicate support of the Cabinet/FHWA's four strategic initiatives as follows (a project may support more than one initiative):

Initiative (number of supporting projects)

1. Manage Congestion (12)
2. Improve Safety (30)
3. Ensure environmental stewardship (7)
4. Improve organizational performance (73)

An assessment of the projects' types of benefits that can reasonably be anticipated was conducted with the following summary results (a project may result in more than one type of benefit):

Benefit Type (number of projects)

a. Cost Savings (28)
b. Time Savings (19)
c. Life and Property Savings (21)
d. Quality Improvement (32)
e. Environmental Improvement (10)
f. Efficiency (53)
g. Sustainability (53)

To be clear, twelve (12) of the research projects, when implemented, would improve highway mobility (congestion--capacity and/or travel time) and thirty (30) would decrease highway crashes (fatalities, injuries and property damage). Some twenty-eight (28) projects' results would reduce cost to either the construction or maintenance of the highway system. Nearly all the research projects' results, when implemented, would increase the sustainability of Kentucky's highway transportation system. That is, taken together, they reduce a broad range of costs, both intrinsic (i.e., construction cost) and extrinsic (i.e., environmental impact), of the system. This overall cost reduction enhances benefits that when taken together, are the measures of the value of the SPR research.

Determining the present value of the benefits having accrued would be a laborious and costly activity. However, seven projects are highlighted in this report to demonstrate the wide diversity of research results and their differing benefits (see the section titled "Research Project Implementation Examples"). One pair of projects in structures and coatings research deals with advanced carbon fiber-reinforced fabric (CFRP) that was demonstrated in the field to result in a 6-to-1 cost savings. A bridge in Carter County was repaired using advanced CFRP materials whose application methods were developed and tested in the center's laboratory. These materials and methods were demonstrated in the field on this bridge that was in need of major renovation or replacement due to structural deficiency. The replacement of the bridge would have cost some $600,000. Using the research results of two SPR companion research projects, the bridge was repaired for $100,000 and its design strength increased. As this advanced technique, based upon SPR research, is used across the Commonwealth the benefits will dramatically accrue over time. The benefit will amount to a multi-million value for the one pair of SPR research projects' results. Not all research projects have these kinds of true dollar benefits. But, some projects' less measurable benefits are highly valuable.

Summary of SPR Research Projects

Project Title	Goals*					Benefits**						
……	1	2	3	4		a	b	c	d	e	f	g
Construction Management												
Night-Time Construction Issues (KTC-00-16 and SPR-00-217)	■	■				■	■				■	■
Contract Time Determination (KTC-01-09/SPR99-195-1F)				■							■	
Concrete QC/QA Specification for Construction (KTC-01-22/SPR187-98-1F)				■		■			■		■	
Quality-Based Prequalification of Contractors (KTC-01-24/SPR212-00-1F)				■					■		■	
Contractor Performed Quality Control (KTC-02-26/SPR222-01-1F)				■					■		■	
Constructibility Issues (KTC-03-17/SPR236-02-1F)				■		■	■		■		■	
Lessons Learned System for Kentucky (KTC-03-25/SPR262-03-1F)				■		■	■		■		■	
Evaluation of Incentive/Disincentive Procedures (KTC-04-27/SPR243-01-1F)				■		■			■		■	
Outsourcing of Project Delivery Functions (KTC-05-11/SPR288-05-2F)				■		■					■	
Environmental Analysis												
Environmental Impacts of Bridge Cleaning Operations (KTC-03-03/SPR224-01-1F)			■			■				■		■
Assessment and Modeling of Stream Mitigation Procedures (KTC-03-14/SPR193-98-1F)			■							■		■
Methods to Protect Water Quality in Karst Areas (KTC-03-30/SPR237-01-1F)			■							■		■
Case Study (4f) Litigation/Rulings (KTC-04-13/SPR225-01-1F)			■	■		■	■			■	■	■
Safety and Health Concerns for Contractor Personnel (KTC-04-24/SPR268-02-1F)		■		■		■		■			■	
Project Commitment Follow-Up (KTC-04-30/SPR210-00-1F)			■	■			■			■	■	■
Financial Analysis												
State Road Fund Revenue Collection Process (KTC-01-17/SPR99-192-1F)				■		■					■	■
Transportation Finance: KY's Structure and National Trends (KTC-02-11/SPR255-02-1F)				■							■	■

*Cabinet/FHWA Goals: 1) manage congestion; 2) improve safety; 3) ensure environmental stewardship; and 4) improve organizational performance

**Benefit Type: a) cost savings; b) time savings; c) life & property savings; d) quality improvement; e) environmental improvement; f) efficiency; and g) sustainability

Summary of SPR Research Projects (continued)

Project Title	Goals*					Benefits**						
……	1	2	3	4		a	b	c	d	e	f	g
Geotechnology												
Resilient Modulus of Kentucky Soils (KTC-01-07/SPR95-163-1F)				■					■		■	
Long Term Benefits of Stabilizing Soil Subgrades (KTC-02-19/SPR196-99-1F)				■		■			■			■
Highway Rock Slope Management Program (KTC-03-06/SPR177-98-1F				■		■	■				■	
Development of Statewide Landslide Inventory Program (KTC-03-07/SPR176-98-1F)				■		■	■				■	
Swelling Pavement: KY 499 Estill Co. (KTC-05-01/SPR270-03-1I)				■		■			■		■	
Kentucky Geotechnology Database (KTC-05-03/SPR227-011-1F)				■			■				■	
Economical Methods of Repairing Landslides (KTC-05-04/SPR180-09-1F)				■		■			■		■	■
Reduction of Stresses on Buried Rigid Highway Structures (KTC-05-05/SPR228-01-1I)				■		■					■	■
Intelligent Transportation Systems (ITS)												
ITS Strategic Plan (KTC-00-5 and SPR-98-188)	■	■		■					■		■	■
Management and Effective Use of Changeable Message Signs (KTC-01-14/SPR233-00-1F)	■	■		■				■			■	
Evaluation of 220 MHz Frequencies for ITS (KTC-02-03/SPR252-01				■		■			■			
ITS Business Plan (for Kentucky) (KTC-01-23/SPR188-98-1F)	■	■		■			■	■			■	■
ITS Statewide Architecture (KTC-03-08/SPR188-98-2F)				■						■	■	■
Maintenance and Operations Plan for ITS (KTC-04-14/SPR241-02-1F)	■	■		■			■	■			■	■
Pavements and Materials												
Revision of Rainfall Intensity Duration Curves (KTC-00-18 and SPR-98-178)				■							■	
Development of a Field Permeability Test for Asphalt Concrete (KTC-01-19/SPR216-00-1F)				■							■	
Cost of Construction Delays and Traffic Control (KTC-02-07/SPR197-99 & SPR218-00-1F)	■	■		■		■	■				■	■

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Summary of SPR Research Projects (continued)

Project Title	Goals*					Benefit**						
……	1	2	3	4		a	b	c	d	e	f	g
Pavements and Materials (continued)												
Longitudinal Construction Joint Compaction in Asphalt Pavement (KTC-02-10/SPR208-00-1F)				■		■	■		■		■	
Movement and Settlement of Highway Bridge Approaches (KTC-02-18/SPR220-00-1F)		■		■					■		■	■
Analysis of Field Permeability and Shear Stress for W. Ky. Parkway (KTC-03-05/SPR245-02-1I)				■					■		■	
Evaluation and Analysis of Highway Pavement Drainage (KTC-03-32/SPR207-00-1F)				■		■			■		■	■
Pavement Management Process Optimization/ Standardization (KTC-04-22/SPR209-00-1F)				■		■					■	■
Planning and Systems Analysis												
Recommended Master Plan to Build a Partnership with the Public (KTC-00-7 & SPR-98-185)			■	■			■		■	■		■
Richmond Public Transportation Study (KTC-01-04/SPR226-00-1F)	■								■		■	■
Impact of New Bypass Route on Local Economy (KTC-01-10/SPR219-00-2I)	■								■		■	
Enterprise Information System Analysis (KTC-02-12/SPR221-00-1F)				■							■	
Roadway Rating Process (KTC-02-30/SPR256-01-1F)		■		■							■	■
2003 Motor Carrier Survey (KTC-04-03/SPR236-02-1F)				■			■				■	■
Kentucky Highway User Survey 2004 (KTC-04-17/SPR236-03-3F)				■					■			
State Traffic Volume Systems Count Estimation Process (KTC-04-28/SPR264-02-1F)				■							■	
Structures and Coatings												
Assessment of Seismic Stability of Highway Embankments (KTC-00-1 and SPR-96-173)		■		■				■				■
GFRP Reinforcement for Concrete Bridge Decks (KTC-00-9 and SPR-96-169)				■					■			■
Flexural Behavior of R/C Beams Strengthened with CRFP (KTC-02-13/SPR200-99-1F)		■		■		■	■		■		■	■

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Summary of SPR Research Projects (continued)

Project Title	Goals*					Benefits**						
……	1	2	3	4		a	b	c	d	e	f	g
Structures and Coatings (continued)												
Shear Strength of R/C Beams Wrapped with CFRC (KTC-02-14/SPR200-99-2F)				■		■	■		■		■	■
Survey of Welding Processes (KTC-03-16/SPR269-03-1F)				■		■			■		■	■
Reinforcement Alternatives for Concrete Bridge Decks (KTC-03-19/SPR215-00-1F)				■					■			■
Evaluation of Service Performance of Bridge Components (KTC-04-20/SPR179-98-1F)				■		■			■		■	■
Traffic and Safety												
2000 Highway Cost Allocation Update (KTC-00-3 and SPR-00-214)				■								■
Expansion of the Roadway Reference Log (KTC-00-4 and SPR-99-201)		■		■							■	
Safety Improvements for Two-Lane Rural Roads (KTC-00-14 and SPR-00-211)		■		■				■				■
Safety Impacts of Rural Road Construction (KTC-01-01/SPR-219-00-1I)		■		■				■				■
Countermeasures for Fatal Crashes on Two-Lane Rural Roads (KTC-01-11/SPR211-002F)		■		■				■	■			■
Analysis of Traffic Growth Rates (KTC-01-15/SPR213-00-1F)	■			■							■	■
Improving Incident Management Response (KTC-01-27/SPR199-98-1F)	■	■		■		■	■	■			■	■
2001 Traffic Safety Issues Opinion Survey (KTC-02-04/SPR249-02-1F)				■				■				■
Investigation of Impact of Large Trucks on Interstate Safety (KTC-02-05/SPR248-02-1F)		■		■				■				■
Evaluation of High Crash Corridors (KTC-02-08/SPR231-01-1F)		■		■				■			■	■
Safety Implications from Design Exceptions (KTC-02-09/SPR230-01-1F)		■		■		■		■		■		■
Traffic Control at Stop Sign Approaches (KTC-03-09/SPR258-03-1I)		■		■				■				■
Roadway Lighting and Driver Safety (KTC-03-12/SPR247-021F)		■		■				■	■	■		■

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Summary of SPR Research Projects (continued)

Project Title	Goals*					Benefits**						
……	1	2	3	4		a	b	c	d	e	f	g
Traffic and Safety (continued)												
Identifying High-Crash Locations and Prioritizing Improvements (KTC-03-15/SPR250-02-1F)		■		■				■			■	■
Crash Rates at Intersections (KTC-03-21/SPR258-03-2I)		■		■				■			■	■
Evaluation of ET2000 Guardrail End Treatment (KTC-04-2/SPR107(4)982F)		■		■				■	■			■
Effect of Pavement Resurfacing on Traffic Safety (KTC-04-2/SPR257-03-1F)		■		■				■			■	■
Access Management for Kentucky (KTC-04-5/SPR251-01-1F)	■	■		■					■		■	■
2004 Highway Cost Allocation Update: Technical Report (KTC-04-7/SPR278-03-1F)				■								■
Evaluation of Accuracy of GPS for Locating Traffic Collisions (KTC-04-8/SPR276-04-1F)				■				■			■	
Context Sensitive Design Workshop and Training (KTC-04-11/SPR204-99-1F)			■	■			■		■	■		■
U-Turns at Signalized Intersections (KTC-04-12/SPR258-03-3F)		■		■								■
Review of Traffic Provisions of KRS/KAR and Ky. Drivers Manual (KTC-05-02/SPR285-05-1F)		■		■								■
Ky. Highway Incident Management Strategic Plan (KTC-05-08/SPR228-05-1F)	■	■		■		■	■		■			■
Evaluation of Auto Incident Recording System (KTC-05-09/SPR277-03-1F)		■		■				■				■

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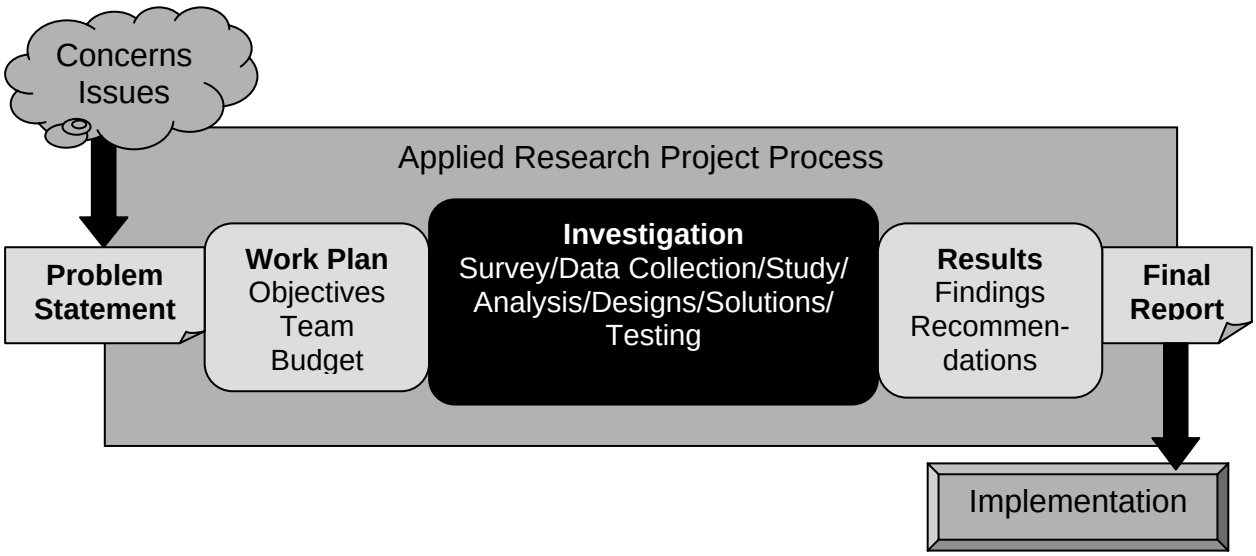
****** Benefit Type: a) cost savings; b) time savings; c) life & property savings; d) quality improvement; e) environmental improvement; f) efficiency improvement; and g) sustainability

Applied Research and Its Value

What Is Applied Research?

Applied research is directed toward discovery of a solution to a specified problem in a relatively short time frame (1-2 years). It may best be defined by describing how it works. The process is as follows:

1. Identify the concerns/issues with clients and provide a **Problem Statement**;
2. Develop a **Work Plan** including objectives to be met with available resources;
3. Carry out an **Investigation** using accepted problem solving methods;
4. Determine the **Results** in terms of findings and recommendations; and
5. Document work in a **Final Report** to the interested parties and assist in implementation as appropriate.



The above diagram show the ideal step-by-step process with key features and the typical outputs from each step from the specific concerns and issues (at the beginning) to the final step of implementation which can be facilitated by the researcher. It should be noted that not all research projects go through the complete sequence; some projects pick-up where another left off or combine the information of several others to produce something useful. Applied research is not very pristine in intent compared with the knowledge building of basic research, but strives to be more practical in providing readily useful results.

Who Does Transportation Research?

Transportation research, like many other kinds of research, is carried out in primarily three venues: government; university; and private firm/industry. The generally acknowledged promise of research to increase knowledge and solve problems ensures government interest. They have the primary responsibility for developing and maintaining the highway network of pavement and structures that is necessary for economic development and national security. At the state and local levels especially, there are heightened concerns about congestion, crashes, environmental harmony, and sustainability. All of the issues and concerns relating to highway infrastructure are amenable to the benefits of research. Applied research can solve problems in transportation resulting in decreased travel time, reduced crashes, increased pavement and structure durability, decreased construction or maintenance cost, reduced construction delay, and increased environmental harmony and sustainability. The primary components of roadway (pavement and structures), vehicle (autos and trucks), driver (old and young) and environment (rural and urban settings) and their interrelations become targets of applied research. Other avenues of transportation research and study include: planning, organization, management, processes and procedures, specifications and standards, and financing.

Most private firm or industry research focuses on the vehicle and its interfaces. Government and much university research focuses on the public infrastructure (the roadway pavement, structures and appurtenances) and how it interfaces. However, government does encourage and fund selected vehicle research that is in the national interest.

In Kentucky, SPR research is the responsibility of the Kentucky Transportation Cabinet. The Cabinet contributes from this program to the National Cooperative Highway Research Program and supports “pooled fund” projects with other states. However, the major avenue of funded research is to the Kentucky Transportation Center at the University of Kentucky. The center grew historically from research facilities and staff

that were transferred from the state's executive branch transportation agency to the university's college of engineering. The center's primary transportation research client is the Kentucky Transportation Cabinet.

In order to more fully answer the question "who does transportation research?" one needs to explore the situation further. Transportation and its issues and problems cover a diverse subject area that stretches from the pothole to the gas pump. Finding successful solutions to the full range of problems typically calls for reaching beyond engineering to the other sciences as well as business, economics and public policy. Finding some solutions requires a truly interdisciplinary team approach. However, efforts all require a close relationship to the client due to the nature of applied research which is aimed at specifically addressing a defined problem with the expectation of finding a solution that can and will be implemented. It is fundamental truth in research that the researcher always considers the research incomplete—researchers are always seeking to find a better way and always wanting more time and funding to do it.

The center's researchers work closely with the Kentucky Transportation Cabinet to define the research program's roster of projects. This is done in annual research focus groups involving Cabinet staff who along with the researchers propose and prioritize projects for funding. The higher priority projects are selected and detailed work programs are prepared by the researchers. Once the project is selected a study advisory committee (SAC) is formed with members of the Cabinet's staff that have interest in the research to be conducted. The SAC and its chairperson approve the work plan and oversee the research progress periodically. At the completion of the research project a report is prepared that documents the findings and recommendations. As part of completing the project the researcher prepares a draft implementation plan comprised of the key recommendations. The implementation plan is finalized by the SAC chairperson and is submitted to the Cabinet's policy and program officials for implementation action. In addition, at the conclusion of each project both the research project team and the study advisory committee review each others performance for the purpose of continuous improvement.

Implementation: Results and Benefits

One way to think about a completed research project's performance is to test against a tiered series of questions:

1. Were the research objectives achieved?
2. Can benefits be attributed to the research results?
3. Will benefits accrue in the real world if the results are implemented?

With any given research project it is clear that the research objectives must be well stated and agreed upon if the first test is to be viable. The second test may be more difficult as the results may span a wide range of development attributes from policy to specifications and the proper expression of benefits may be qualitative, semi-quantitative, or quantitative. The third test has to do with the acceptance and implementability of something new or different that may be recommended from the research. This may require steps that go far beyond the purview of the research team, but may be facilitated by it. There is also the possibility of some short-term and then long-term benefits of initial research and subsequent development actions. Nevertheless, the challenge for those in the business of applied research is to clearly demonstrate and explain the benefits that accrue from their work in ways that are generally understandable and reasonable.

In order to build a bridge between the "Final Report" of a research project and the realization of benefits, the Kentucky SPR program uses an implementation plan. This device is a form that is prepared at the conclusion of a project. The plan is in a form that lists each recommendation and its responsible party (in the Ky. Transportation Cabinet), start date, action steps, finish date, and budget. In some cases additional work may be required by the research team or an individual researcher may lead a workshop that is aimed at explaining new recommended processes or procedures. However, in most cases it is the state agency's professionals and technical staff that must carry out the necessary steps for a research recommendation or the research results to be implemented and begin accruing benefits. This process was not in place for the entire period of this report, but is being seen as useful in assuring that research reports do not simply collect dust on shelves or take up space on a Web server.

Transportation Research in Kentucky

Kentucky Transportation Cabinet and the Kentucky Transportation Center

In 1941, the Kentucky Department of Highways located its Division of Research adjacent to the University of Kentucky campus in Lexington. The Kentucky Transportation Cabinet transferred the Division of Research facilities and employees to the University of Kentucky in 1981. This was the beginning of the Kentucky Transportation Research Program in the UK College of Engineering. It was combined in 1988 with the federally funded Local Transportation Assistance Program (technology transfer) at the University of Kentucky to form the present Kentucky Transportation Center that has a mission for research, technology transfer and education.

SPR Research Program and Projects

The SPR research program was established to provide states with a pool of dedicated funding resources to address specific issues that are unique and important at the state level. Major long-term research is typically conducted at the national level by FHWA or through NCHRP. SPR funds are used proportionately for applied, short-term, research projects with the expectation of improving the safety, efficiency and quality of Kentucky's highway system. During the period of this report the SPR funds invested in research averaged about $3 million annually (this is less than 0.25% of available transportation funds). During this same time 80 applied research projects were completed and the results documented. Research was carried out by professional researchers, faculty, laboratory and field technicians and a variety of management and administrative support staff numbering over 45 full-time staff and involving 8 faculty members.

Work was carried out in nine research program areas as described below:

1. Construction Management – This area reflects the growing interest in the processes and procedures for more efficient and effective roadway construction and project management. Nine projects were completed as follows:

Night-Time Construction Issues (KTC-00-16 and SPR-00-217)
Contract Time Determination (KTC-01-09/SPR99-195-1F)
Concrete QC/QA Specification for Construction (KTC-01-22/SPR187-98-1F)
Quality-Based Prequalification of Contractors (KTC-01-24/SPR212-00-1F)
Contractor Performed Quality Control (KTC-02-26/SPR222-01-1F)
Constructibility Issues (KTC-03-17/SPR236-02-1F)
Lessons Learned System for Kentucky (KTC-03-25/SPR262-03-1F)
Evaluation of Incentive/Disincentive Procedures (KTC-04-27/SPR243-01-1F)
Outsourcing of Project Delivery Functions (KTC-05-11/SPR288-05-2F)

2. Environmental Analysis – Concern for the environment is a major factor that impacts all phases of transportation project development and highway system maintenance. Work focuses on enhancing the understanding of environmental impacts and ways to better accommodate these issues in project delivery. Six projects were completed:

Environmental Impacts of Bridge Cleaning (KTC-03-03/SPR224-01-1F)
Assessment and Modeling of Stream Mitigation (KTC-03-14/SPR193-98-1F)
Methods to Protect Water Quality in Karst Areas (KTC-03-30/SPR237-01-1F)
Case Study (4f) Litigation/Rulings (KTC-04-13/SPR225-01-1F)
Safety/Health Concerns - Contractor Personnel (KTC-04-24/SPR268-02-1F)
Project Commitment Follow-Up (KTC-04-30/SPR210-00-1F)

3. Financial Analysis – Revenue policy and financial management improvement is a major interest of this research area in an era of increasingly scarce resources. Two projects were completed as follows:

State Road Fund Revenue Collection Process (KTC-01-17/SPR99-192-1F)
Transportation Finance: KYs Structure & Trends (KTC-011/SPR255-02-1F)

4. Geotechnology – This area focuses on the soils and geology throughout Kentucky and how best to stabilize or use these resources in the construction of highways. Eight research projects were completed:

Resilient Modulus of Kentucky Soils (KTC-01-07/SPR95-163-1F)

Long Term Benefit of Stabilizing Soil Subgrades (KTC-02-19/SPR196-99-1F)
Highway Rock Slope Management Program (KTC-03-06/SPR177-98-1F)
Development of State Landslide Inventory (KTC-03-07/SPR176-98-1F)
Swelling Pavement: KY 499 Estill Co. (KTC-05-01/SPR270-03-1I)
Kentucky Geotechnology Database (KTC-05-03/SPR227-011-1F)
Economical Methods of Repairing Landslides (KTC-05-04/SPR180-09-1F)
Reduction of Stress on Buried Hwy Structures (KTC-05-05/SPR228-01-1I)

5. Intelligent Transportation Systems – Significant improvements to the safety and mobility are available with the systematic application of advanced technologies applying sensors, computers and a variety of communication devices. Six research project reports were issued:

ITS Strategic Plan (KTC-00-5 and SPR-98-188)
Management & Use of Changeable Message Signs (KTC-01-14/SPR233-00-1F)
Evaluation of 220 MHz Frequencies for ITS (KTC-02-03/SPR252-01)
ITS Business Plan (for Kentucky) (KTC-01-23/SPR188-98-1F)
ITS Statewide Architecture (KTC-03-08/SPR188-98-2F)
Maintenance and Operations Plan for ITS (KTC-04-14/SPR241-02-1F)

6. Pavements and Materials – The design of roadway pavements, construction materials, drainage and life-cycle performance is the focus of this area. Eight research projects were completed as follows:

Revision of Rainfall Intensity Duration Curves (KTC-00-18 and SPR-98-178)
Development of Field Permeability Test for Asphalt (KTC-01-19/SPR216-00-1F)
Cost of Construction Delays (KTC-02-07/SPR197-99 & SPR218-00-1F)
Longitudinal Construction Joint Compaction (KTC-02-10/SPR208-00-1F)
Movement/Settlement of Hwy Bridge Approaches (KTC-02-18/SPR220-00-1F)
Analysis of Field Permeability (W. Ky. Parkway) (KTC-03-05/SPR245-02-1I)
Evaluation of Highway Pavement Drainage (KTC-03-32/SPR207-00-1F)
Pavement Management Process Optimization (KTC-04-22/SPR209-00-1F)

7. Planning and Systems Analysis – The analysis of existing systems and planning for the future requires interdisciplinary expertise and participatory methods combined with advanced techniques for polling, modeling and visualization. Eight research projects were completed as follows:

Master Plan to Build a Partnership with the Public (KTC-00-7 & SPR-98-185)
Richmond Public Transportation Study (KTC-01-04/SPR226-00-1F)
Impact of New Bypass Route on Local Economy (KTC-01-10/SPR219-00-2I)
Enterprise Information System Analysis (KTC-02-12/SPR221-00-1F)
Roadway Rating Process (KTC-02-30/SPR256-01-1F)
2003 Motor Carrier Survey (KTC-04-03/SPR236-02-1F)
Kentucky Highway User Survey 2004 (KTC-04-17/SPR236-03-3F)
State Traffic Volume Count Estimation Process (KTC-04-28/SPR264-02-1F)

8. Structures and Coatings – This area focuses primarily on highway bridge structures, the use of fiber reinforced composites and durable coatings application. Seven research projects were completed:

Seismic Assessment Stability of Hwy Embankments (KTC-00-1 & SPR-96-173)
GFRP Reinforcement for Concrete Bridge Decks (KTC-00-9 and SPR-96-169)
Behavior of R/C Beams Strengthened with CRFP (KTC-02-13/SPR200-99-1F)
Shear Strength of R/C Beams Wrapped with CFRC (KTC-02-14/SPR200-99-2F)
Survey of Welding Processes (KTC-03-16/SPR269-03-1F)
Reinforcement Alternatives for Bridge Decks (KTC-03-19/SPR215-00-1F)
Evaluation of Performance of Bridge Components (KTC-04-20/SPR179-98-1F)

9. Traffic and Safety – Traffic forecasting, traffic control devices, safety and crash analyses, incident management, access management, and the design of safety improvement counter measures is the focus of this area.

2000 Highway Cost Allocation Update (KTC-00-3 and SPR-00-214)
Expansion of the Roadway Reference Log (KTC-00-4 and SPR-99-201)
Safety Improvements for Two-Lane Rural Roads (KTC-00-14 and SPR-00-211)

Safety Impacts of Rural Road Construction (KTC-01-01/SPR-219-00-1I)
Countermeasures for Fatal Crashes on Rural Roads (KTC-01-11/SPR211-002F)
Analysis of Traffic Growth Rates (KTC-01-15/SPR213-00-1F)
Improving Incident Management Response (KTC-01-27/SPR199-98-1F)
2001 Traffic Safety Issues Opinion Survey (KTC-02-04/SPR249-02-1F)
Impact of Large Trucks on Interstate Safety (KTC-02-05/SPR248-02-1F)
Evaluation of High Crash Corridors (KTC-02-08/SPR231-01-1F)
Safety Implications from Design Exceptions (KTC-02-09/SPR230-01-1F)
Traffic Control at Stop Sign Approaches (KTC-03-09/SPR258-03-1I)
Roadway Lighting and Driver Safety (KTC-03-12/SPR247-021F)
High-Crash Locations & Prioritizing Improvement (KTC-03-15/SPR250-02-1F)
Crash Rates at Intersections (KTC-03-21/SPR258-03-2I)
Evaluation of ET2000 Guardrail End Treatment (KTC-04-2/SPR107(4)982F)
Effect of Pavement Resurfacing on Traffic Safety (KTC-04-2/SPR257-03-1F)
Access Management for Kentucky (KTC-04-5/SPR251-01-1F)
2004 Hwy Cost Allocation Update: Technical Report (KTC-04-7/SPR278-03-1F)
Evaluation of GPS for Locating Traffic Collisions (KTC-04-8/SPR276-04-1F)
Context Sensitive Design Workshop and Training (KTC-04-11/SPR204-99-1F)
U-Turns at Signalized Intersections (KTC-04-12/SPR258-03-3F)
Traffic Provisions Review – KRS & Drivers Manual (KTC-05-02/SPR285-05-1F)
Ky. Highway Incident Management Strategic Plan (KTC-05-08/SPR228-05-1F)
Evaluation of Auto Incident Recording System (KTC-05-09/SPR277-03-1F)

Complementary Research Initiatives and Technology Transfer

While SPR research represents the core applied research activity at the center other complementary research initiatives are carried out. These initiatives have included research work for:

- Kentucky State Police (Safety Statistics)
- U.S. Navy (Structures and Coatings)
- Toyota (Coatings)

Project work, including SPR, has required the center to collaborate with other research entities that are part of the university including:

- UK College of Engineering
- Gatton College of Business and Economics (UK)
- Martin School of Public Administration (UK)
- Kentucky Geological Survey (UK)
- UK College of Arts and Sciences (English and Geography Departments)

Some projects have involved researchers beyond UK including:

- Georgia Tech
- Northwestern University
- University of Arizona
- University of Buffalo
- University of Louisville
- University of Tennessee

The center's researchers also work collaboratively with a variety of private sector planning and engineering consultants that are nationally recognized.

The center has particularly distinguished itself, in close cooperation with the Kentucky Transportation Cabinet, in two areas:

- ITS/CVO Research, Deployment and Training – This work began as with Kentucky being selected as a lead state for an ITS commercial vehicle operations demonstration and has resulted in center staff being recognized for outstanding contributions by the USDOT; and
- CSD/CSS Research and Training – This work began as part of an SPR project and has broadened to include both national research and training for some 12 states in Context Sensitive Solutions.

Technology transfer staff provides workshops and training events, how-to manuals, expert advice, legislative and regulatory news, on-site technical assistance and library resources. It conducts an ongoing Roads Scholar and Road Master Training Program for local governments. Workshops are held on the Road Surface Management System, Sign Inventory Management System and Low Cost Safety Improvement. A "Safety Circuit Rider Program" has been initiated to assist cities and counties in the reduction of crashes on rural two-lane roads. Much of the technology transferred to local governments is based on SPR research and documented best practices from throughout the country.

Research Project Implementation Examples

Nighttime Construction Issues

Long-Term Benefits of Stabilizing Highway Soil Subgrades

Intelligent Transportation Systems (ITS) Plans and Architecture

Development of a Field Permeability Test for Asphalt Concrete

Implementation of Advanced Carbon Fiber Composites for Repairing Bridges

High Crash Location Analysis and Safety Improvement Prioritization

Construction Management

Project:

Nighttime Construction Issues

(KTC-00-16 and SPR-00-217)

Demand is increasing for performing construction and maintenance operations at night to reduce traffic conflicts. However, there are significant issues to be considered.

Objectives:

- Determine past results of night-time construction.
- Identify the advantages and disadvantages.
- Survey highway contractors to determine methods to improve the process.
- Make recommendations for successful implementation of the practice.

Results:

The research findings include –

1. **Success of night work varies based on the type of work, experience of the contractor, and location of the project.**
2. **Night work's effect on quality/productivity appears neutral or slightly positive.**
3. **Many factors affect night-time construction and agencies need to evaluate a project's potential -- seven parameters were identified including: traffic, economic, environmental, and legal (a method of evaluation was developed).**

A set of 17 recommendations were made including the need for the contractor to prepare a detailed night-time work plan.

Implementation:

An evaluation method/form was developed and is used by the Cabinet to determine the practicality of performing a construction project at night. The major issues considered are --

- traffic
- economic
- social
- construction

The evaluation form is easy to understand and very useful for construction project planning.

Benefits:

The study identified issues for the Cabinet and contractors to consider and understand the impacts when performing night-time construction. By addressing these issues for each project they will --

- **Improve driver safety**
- **Increase adequacy of lighting**
- **Improve speed enforcement**
- **Reduce noise impacts**
- **Attend to worker fatigue and safety**
- **Improve media information campaign**

Geotech

Project:

Long-Term Benefits of Stabilizing Highway Soil Subgrades with Chemical Admixtures

(KTC 02-19/SPR196-99-1F)

There was a need to conduct a comprehensive review and assessment of the long-term benefits of subgrade chemical stabilization as practiced in Kentucky.

Objectives:

The purpose of this study was to –

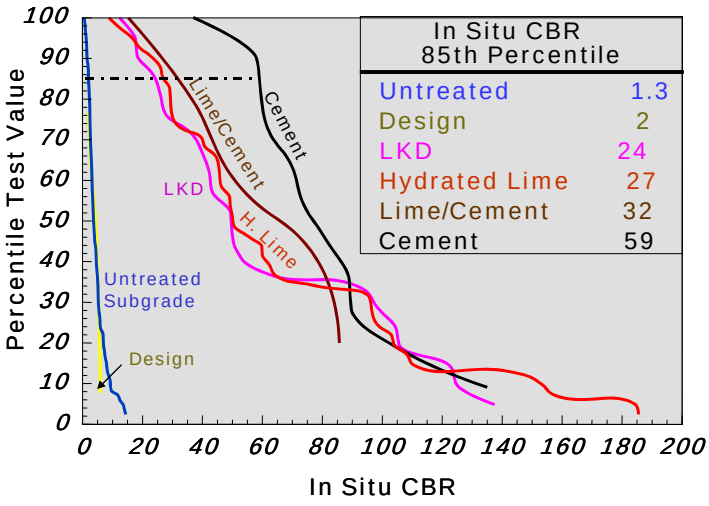
- Determine long-term durability of chemically stabilized soil subgrades.
- Observe flexible pavement performance on stabilized soil subgrades.

Results:

1. **Testing proved that stabilized subgrade strengths were much larger than non-stabilized subgrades after 7 to 30 years.**
2. **Structural credit can be given to the stabilized subgrade as part of the pavement design.**
3. **CBR strength of soil subgrades must be greater than 6 to prevent pavement failures during construction.**
4. **Poor engineering properties of soils are vastly improved by chemical admixtures.**

Implementation:

- Stabilization of all newly constructed highway soil subgrades with a CBR value of 6, or less, is recommended by the Cabinet.
- Chemical subgrade stabilization is now a standard in highway pavement construction and is given structural credit in design.



Benefits:

- **Chemical stabilization is an economical means of improving the poor engineering strengths of Kentucky soils.**
- **Costly pavement failures during and after construction are prevented.**
- **Structural design credit is now given to stabilized subgrades which lowers cost.**
- **Longevity and subgrade strength durability are maintained for thirty years or more.**
- **Reduces soil subgrade swell that affects pavement performance and rideability.**
- **Cost benefit ratio of this research is greater than 20 and increases as more projects use chemical stabilization.**

Intelligent Transportation Systems (ITS)

Project:

Development of Kentucky ITS:

- **Strategic Plan** (KTC-00-05 / SPR 188-98-1F)
- **Business Plan** (KTC-01-23 / SPR 188-98-1F)
- **Statewide Architecture** (KTC-03-08 / SPR 188-98-2F)

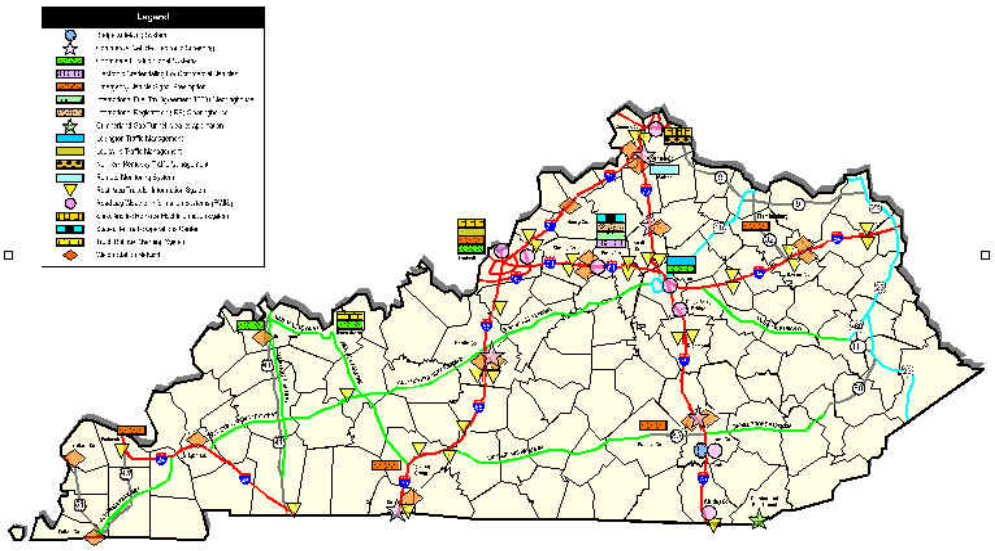
Objectives:

- Provide a vision for ITS in Kentucky.
- Develop specific program goals.
- Provide a list of priority projects.
- Develop a schedule for deployment.
- Provide an ITS "architecture" to ensure projects are integrated and interoperable.

Results:

Development of the ITS Strategic Plan and Business Plan provides a vision for ITS in Kentucky, a list of specific goals, and a set of projects to be implemented, with assigned priorities and timeframes.

The ITS Statewide Architecture provides, for the first time, documentation of all existing and planned ITS technologies in Kentucky. It helps to ensure that all new projects are integrated and interoperable with existing systems.



Implementation:

The Strategic and Business Plans allow decision-makers at the Kentucky Transportation Cabinet to incorporate ITS technologies into the six-year plan for highway system development and to ensure that ITS deployments meet the most urgent needs of users.

Having a ***Statewide Architecture*** is a requirement for receiving Federal ITS funds, and all new projects must be included in the system architecture. Its establishment by the Cabinet ensures that all appropriate standards are identified and incorporated into each new ITS project in Kentucky.

Benefits:

Kentucky is a leader in the development and deployment of ITS technologies. This research allows Kentucky to enhance its position with a stated vision, goals, and specific project funding priorities to meet urgent needs.

Having a statewide system architecture substantially increases coordination so that systems are able to work together and share data seamlessly. Kentucky is able to continue taking aggressive advantage of federal ITS funding opportunities.

Project:

Development and Proposed Implementation of a Field Permeability Test for Asphalt Concrete (KTC-01-19/SPR 216-00-1F)

A number of Kentucky superpave asphalt surfaces in Kentucky exhibit fairly high permeability. This allows water to migrate to the surface and freeze during cold weather. A safety hazard results along with a maintenance requirement for crews to spread salt in these areas.

Objectives:

- Review recent permeability research.
- Develop a rapid field test method.
- Define acceptable permeability rates.
- Develop a QC/QA specification and procedure for construction.

Results:

- **A Kentucky test method was developed to measure the in-place permeability of asphalt concrete.**
- **A specification was written to assist the Cabinet in determining acceptable levels of asphalt pavement permeability.**
- **A mathematical model was developed to predict the permeability of an asphalt pavement, based on the mixture gradation.**

Implementation:

- Several asphalt mixtures have been designed using the new design model.
- Significantly reduced surface permeability has resulted.

The proposed specification and model was being used during the 2005 construction season on several new asphalt surfaces.

Photographs show the testing device and its use on the roadway pavement.

Benefits:

The benefits of this research are just beginning to accrue. With more surfaces designed to the new specification and tested for compliance both the safety hazards due to the previous asphalt pavement porosity and the maintenance requirement for increased salting will be significantly reduced. The benefits will reasonably include a reduction in crashes and property damage.

Structures and Coatings

Project:

Implementation of Advanced Carbon Fiber Composites Technology for Repairing and Strengthening Kentucky Bridges (KY SPR 99-200)

Objectives:

- Laboratory testing of reinforced concrete beams strengthened with carbon fiber-reinforced polymer (CFRP) fabric and laminates.
- Field application and monitoring of CFRP fabric and laminates on Kentucky bridges.

Results:

KTC laboratory tests showed that shear strength is increased up to 33% for concrete beams wrapped with CFRP fabric and flexural strength is increased up to 58% for beams strengthened with two CFRP laminates.

Implementation:

*(1) CFRP Strengthening of the **Carter County Bridge** --*

- The bridge on KY 3297 had severe cracks which would indicate replacement of the entire super-structure costing over $600,000.
- The bridge was repaired using CFRP fabric costing $100,000 with little disruption to traffic.
- There has been no movement in the bridge cracks after nearly four years.

*(2) CFRP Laminate Strengthening of the **Louisa-Fort Gay Bridge** --*

- The beams in three of the four reinforced concrete spans of the bridge had severe flexural cracks.
- The bridge was repaired using CFRP laminates without any disruption to traffic.
- After nearly two years, there has been no movement in the bridge cracks.

Photographs show: the bridge type that can benefit from CFRP retrofit, the typical nature of concrete beam cracking, and the application of the advanced composite laminates.

Benefits:

Both KTC field applications of CFRP retrofits have been a great success. A major benefit of retrofitting bridges with CFRP is the ability to repair with little or no disruption to traffic. This is in addition to significant (6 to 1) cost savings over replacement or major structural rehabilitation of a bridge. The benefits of CFRP applications will continue to grow and accrue as additional bridges are selected for retrofit throughout the Commonwealth.

Traffic and Safety

Project:

High Crash Location Analysis and Safety Improvement Prioritization

(KTC-03-15/SPR 250-02-1F)

The crash buildup program used by Kentucky was outdated and incompatible with the newly adopted (2000) crash report format.

Objectives:

Develop improved methods to --

- Identify and evaluate high vehicle crash locations.
- Determine and prioritize appropriate roadway safety improvements.

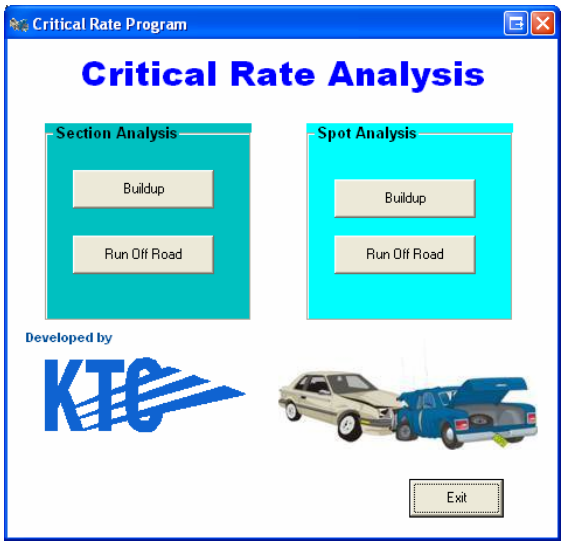
Results:

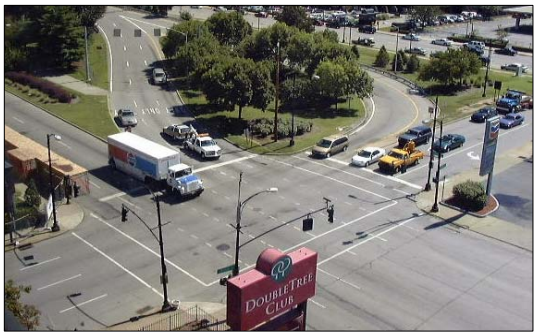
The research team --

1. **Reviewed existing Kentucky procedures as well as those used in other states.**
2. **Recommended improved methods of identifying, analyzing and prioritizing high frequency crash site locations.**
3. **Developed software to determine benefits and costs of potential hazard elimination projects.**
4. **Recommended revisions for updating and enhancing the program in a PC-based system.**

Implementation:

- Cabinet installed the new program software developed from the research.
- Cabinet personnel were trained in its use by KTC staff.
- Modifications have lead to increased program functionality.





Benefits:

The new crash buildup program has become a routine tool used by both central and district offices for assessing crash frequency as criteria for identifying potential locations for safety improvements. The enhanced benefit cost procedure has been implemented and is currently being used in hazard elimination project selection. Both the effectiveness and the efficiency in selecting locations for safety improvement have been enhanced.

IMPLEMENTATION PLAN

PROJECT NAME:	KTC PROJECT NO.
PRINCIPAL INVESTIGATOR:	SAC CHAIR:

OBJECTIVES:

RESEARCH RECOMMENDATIONS	STATUS	RESPONSIBLE PARTY(Cabinet)	START DATE	ACTION STEPS	FINISH DATE	BUDGET
Comments:						
Comments:						
Comments:						
Comments:						
Comments:						
Comments:						
Comments:						

Appendix

Implementation Plan Form

Research Project Abstracts by Program Area

CONSTRUCTION MANAGEMENT

KTC-00-16 **"Nighttime Construction Issues," Donn Hancher and Tim Taylor, July 2000. SPR-00-217**

Abstract: This report addresses several issues to consider when considering performing highway construction work in Kentucky at night. Surveys of other state departments of transportation and Kentucky highway contractors were made to identify best practices and concerns. An advisory committee of experienced KyTC engineers plus contractor representatives met extensively to identify successful approaches for handling key issues which arise on night-time construction projects.

Seventeen specific recommendations have been proposed to enhance the Cabinet's use of night-time construction for its projects. These cover several issues related to night-time work, including contract requirements, traffic control, law enforcement, personnel issues, lighting and public awareness. A method (the Night-Time Project Evaluation Form) was also developed for evaluating a proposed construction project as a candidate for night-time work.

If properly implemented, night-time construction can greatly decrease the duration of highway construction projects, greatly reduce road user delays and associated costs, while providing a safe environment for both workers and the traveling public.

KTC-01-09/SPR99-195-1F **"Kentucky Contract Time Determination," Donn E. Hancher and Raymond Werkmeister, Jr., May 2001.**

Abstract: This paper reports on the results of research that was funded by the Kentucky Transportation Cabinet (KyTC) to develop a new method for determining construction contract time for its highway construction contracts. The current and other DOT systems were analyzed to determine how a new system could provide better estimated durations. It was pre-determined that a pc computer based system was best suited. The development of the system input was developed from KyTC engineers with the construction experience. The study advisory committee worked with Kentucky Transportation Center research engineers to develop the basis for the new contract time determination system, called KY-CTDS.

The KY-CTDS program provides a conceptual estimating tool for predicting construction contract time for the Kentucky Department of Highways. It uses the pre-determined project classifications with only the major activities that control the project duration. Production rates and activity relationships were determined and are included in the program. Final adjustments in the project can be easily made by KyTC engineers. This system utilizes Microsoft Project 98 and Microsoft Excel Version 7.0 software operating on a personal computer. System outputs include a graphical bar chart schedule for estimating the contract time for bidding purposes. System output may also help in resolving construction disputes. The program is not suitable for detailed scheduling of construction operations.

KTC-01-22/SPR187-98-1F "Development of Concrete QC/QA Specifications for Highway Construction in Kentucky," Kamyar C. Mahboub and Donn E. Hancher, July 2001.

Abstract: There is a growing trend toward quality-based specifications in highway construction. A large number of quality control/quality assurance (QC/QA) specifications shift the responsibility of day-to-day testing from the state DOH to the contractor. This requirement for contractor-performed quality control testing has been partly due to the fact that state agencies are operating with a smaller pool of employees compared to previous years. Another driving force has been the application of performance-based specifications and realization that the contractor and the producer need some degree of flexibility in order to be more efficient and innovative. This report presents the background information behind the development of the new QC/QA Concrete specifications in Kentucky. Findings of this study have already been implemented in the form of a Special Note for QC/QA Concrete, which is expected to be fully implemented by the year 2002. The QC/QA Special Note encourages the Contractor to produce a consistent quality product by giving incentives. Conversely, it penalizes the Contractor for poor quality, and/or inconsistent quality. The Special Note has been written with quality and innovation in mind. That is why it allows the Contractor and the Producer to follow the ACI-318 procedures for concrete mix design as well as the Kentucky Transportation Cabinet recipe mixes.

KTC-01-24/SPR212-00-1F "Quality-Based Prequalification of Contractors," Donn E. Hancher, Sean E. Lambert, & William F. Maloney, August 2001.

Abstract: This report summarizes the efforts to provide the Kentucky Transportation Cabinet with a system for evaluating the quality of the performance of contractors on highway construction projects and using the evaluation in the Cabinet's annual prequalification process for contractors. Contacts with several other state departments of transportation were made to identify best practices and concerns. An advisory committee of experienced KyTC engineers plus Kentucky contractor representatives met extensively to develop the final performance evaluation documents to be used in the process.

A performance evaluation process was developed to evaluate a contractor's work on projects and the results from all of the contractor's projects used in the annual prequalification process. A performance evaluation process was also developed to allow contractors to evaluate the performance of the Cabinet's Department of Highways (DOH) on projects.

These new evaluation processes will begin implementation in December, 2001. Once implemented, the new process will enable the Cabinet to evaluate the performance of contractors on its projects and to recognize performance more accurately in the prequalification process. It will also be able to use the input from contractors on the DOH's performance for quality improvement of its own processes and practices.

KTC-02-26/SPR-222-01-1F "Contractor Performed Quality Control on KyTC Projects," Donn E. Hancher, Yuhong Wang, and Kamyar C. Mahboub, August 2002.

Abstract: This report addresses issues related to transferring the responsibility for quality control from the Kentucky Transportation Cabinet (KyTC) to construction contractors. Surveys of the KyTC, other state departments of transportation, and Kentucky highway contractors were done to identify the advantages, concerns, and modifications of the Contractor Performed Quality Control (CPQC) program. An advisory committee of experienced KyTC engineers, FHWA representatives, and contractor representatives met periodically to identify approaches for handling key issues of the program.

Several key topics related to CPQC are presented in this report, with emphasis on quality control (QC)/quality assurance (QA) administration, QC/QA procedures, quality acceptance and verification testing, and CPQC training. Specific issues related to CPQC pay items in Kentucky are also discussed. Several recommendations have been proposed to enhance the program.

If properly implemented, CPQC can improve a contractor's work performance and help relieve the State's burden for inspection. Additional monitoring of the program is necessary to make further improvements and to include other pay items.

KTC-03-17/SPR236-02-1F "Constructibility Issues on KyTC Projects," Donn E. Hancher, Joseph J. Thozhal and Paul M. Goodrum, July 2003.

Abstract: Constructibility is defined by the American Association of State Highway and Transportation Officials Subcommittee on Construction as "a process that utilized construction personnel with extensive construction knowledge early in the design stages of projects to ensure that the projects are buildable, while also being cost-effective, biddable, and maintainable". A successful constructibility review process for a transportation agency must follow an established methodology similar to value engineering. The process must be flexible and address the critical issues impacting transportation construction projects, such as ease of construction, environmental factors, construction phasing and scheduling, project safety, and accommodation of future maintenance and operations. To obtain maximum benefit from a constructibility review, it must be initiated early in the planning phase of the project and continue through design and construction.

Several key topics related to CRP are presented in this report, with emphasis on the KyTC Project Development Process, and constructibility input to this process. Several recommendations have been proposed to enhance the program.

KTC-03-25/SPR262-03-1F "Lessons Learned System for Kentucky Transportation Projects," Paul M. Goodrum, Mohammed F. Yasin and Donn E. Hancher, August 2003.

Abstract: A system of collecting, archiving, and disseminating lessons learned is a critical component of experienced-based processes, such as the design and construction of roadway and bridges. This report examines the development of a centralized, web-based Lessons Learned System for the Kentucky Transportation Cabinet. The research developed a working prototype of a lessons learned system that functions off of centrally located databases making it easier to administer and

update. The Lessons Learned System was designed to accept both text and attachments through file uploads while maintaining relationships between these items of information in terms of a lesson learned. The report describes how the Lessons Learned System can be integrated into both the existing post construction review process and the proposed constructibility program within the Cabinet. Although the system was designed to support the post construction review and constructibility processes, its architecture will support other processes within the Cabinet where the archiving of lessons learned is important. The project also developed a process for maintaining the lessons learned system that includes the role of a gatekeeper to insure the quality and accuracy of the submitted and stored lessons.

KTC-04-27/SPR243-01-1F "Evaluation of Current Incentive/Disincentive Procedures in Construction," Brad Rister and Yuhong Wang, October 2004.

Abstract: This study was initiated to take an in-depth look at the current time and material incentive/disincentive program associated with highway construction projects in Kentucky. The current incentive/disincentive program was first initiated in the mid to late 90's. However, not until recently had some of the original mechanisms of the program been revisited and/or up-dated.

From the early stages of this study it was anticipated that many of the concerns regarding the use of both time/material incentives and disincentives on highway construction projects in Kentucky would be addressed. Therefore, at the onset of this project the study advisory committee made a tremendous effort to devise a working plan for this study that would evaluate both the time and material incentive and disincentive program. In addition to the evaluation of the program, tremendous effort was also undertaken to answer some age old questions regarding the quality of projects that have received time incentive bonuses in the past.

KTC-05-11/SPR288-05-2F "Outsourcing of KyTC Project Delivery Functions," Donn E. Hancher, April Brenneman and Paul M. Goodrum, June 2005.

Kentucky's Highway Incident Management Strategic Plan consists of a mission statement, 4 goals, 16 objectives, and 49 action strategies. The action strategies are arranged by priority and recommended time frame for implementation. When implemented, the action strategies will help Kentucky achieve its primary goals for incident management: 1) improved safety of responders, highway workers, and motorists; 2) reduced traffic delay; 3) improved motorist awareness; and 4) improved responder and highway worker preparedness.

ENVIRONMENTAL ANALYSIS

KTC-03-03/SPR224-01-1F "Environmental Impacts of Bridge Cleaning Operations," Sudhir Palle and Theodore Hopwood II, February 2003.

Abstract: Cleaning (washing) operations of existing leaded paints on bridges were studied to determine the level of lead contamination in the resulting wastewater. Twelve experimental

overcoating projects were let on bridges with various types of existing paint in varying states of deterioration, The projects employed different washing pressures ranging from 2500 psi to 10000 psi and various wash nozzles (fan and 0^o spinner tips). KyTC standard filtration was used on 10 projects and 2 projects used an experimental filtration unit having a sand filter and two types of chemical filter media.

Prior to painting, the existing paint was analyzed for thickness, adhesion, and lead content. Wastewater generated during maintenance painting operations (potable, unfiltered and filtered) was sampled and analyzed for lead content (total and dissolved), total suspended solids and pH. No clear correlations were obtained between lead in the wastewater, wash pressures, nozzle type, or any of the existing paint parameters tested. The sand filter and chemical filter media of the experimental filtration unit provided significant removal of lead from wastewater.

KTC-03-14/SPR193-98-1F "Assessment and Modeling of Stream Mitigation Procedures," Bernadette Dupont and Sudhir Palle, May 2003. (See KTC-99-52, interim report)

Abstract: As population increases, so does the need to improve and augment the road network. Construction of new roadways or modification of existing roads often requires diversion or modification of streams. If a stream is disturbed, government regulations require mitigation or compensatory replacement of the affected area in a similar environment. Stream mitigation is of particular importance in Kentucky, as Kentucky ranks second in the United States for having the most miles of waterways. Consequently, stream mitigation has become a significant factor in roadway construction costs. To date, no studies have been made to assess the execution of the mitigation plans or to determine the performance of mitigation projects. In a move to rectify this situation, the Kentucky Transportation Cabinet requested this study.

KTC-03-30/SPR237-01-1F "Evaluation of Methods to Protect Water Quality in Karst Areas: Phase I," Jennifer Webster, Dhandayudhopani Ramilingam and Sudhir Palle, October 2003.

Abstract: The primary focus of this report is two-fold; to provide a literature review on what has been previously learned about highway runoff in related to karsts aquifers and to characterize a karsts highway site in Kentucky that can be used to evaluate a variety of best management practices. From research findings, the main sources of pollutants in highway runoff come from vehicles, atmospheric fallout, and precipitation. The behavior of pollutants and their interaction with the environment can dictate where they will be found and how to best minimize their effects. Although it would seem that traffic volumes would greatly influence the accumulation of pollutants on roadways, past studies have not proven this. Instead, no clear relationship between traffic and water quality has been reported. Removal processes such as air turbulence (both natural and the result of vehicles) limit the accumulation of solids and other pollutants on road surfaces, thereby obscuring the relationship between the traffic volume and runoff loads. Of the various precipitation characteristics, intensity was found to have the greatest impact on the type and quantity of pollutants found in highway runoff. This was expected due to the greater velocity traveled by runoff during high rain intensity events which does not allow suspended particles a chance to settle out and often results in greater friction along the runoff travel routes. In all experiments previously conducted, highway paving material

appears to have minimal impact. Of the best management practices examined, vegetated control received the highest recommendation because of their wide adaptability, low costs, and minimal maintenance requirements.

Water quality testing results from the location off I-65 South demonstrated very low levels of select pollutants, when compared to national averages. The existing vegetative controls in the highway median and along the drainage paths are considered to be effective at mitigating a large quantity of runoff from reaching the drainage point into sinkhole.

KTC-04-13/SPR225-01-1F "Case Study (4f) Litigation/Rulings," Len O'Connell and Theodore Hopwood, June 2004.

Abstract: This study addresses issues related to compliance with Section 4(f). It produced two deliverables: 1) a guidance manual to assist Cabinet personnel in the assessment and handling of projects that encounter 4(f) properties; and 2) a review of court cases to establish the standards used by the courts when evaluating a Section 4(f) situation. The latter is an appendix to the guidance manual. By referring to the manual Cabinet employees will be able to: 1) Conduct an assessment of proposed alternatives to evaluate prudence and feasibility of a proposed project alternative; 2) Prepare 4(f) documentation to justify the taking of protected property; 3) Apply context-sensitive design principals to mitigate impacts and stakeholder concerns; 4) Identify potential 4(f) involvement on private properties; 5) Identify mitigation measures to minimize potential harm to 4(f) resources; 6) Develop a decision-making process where 4(f) impacts are unavoidable- - the latter based on judicial rulings arising from 4(f) litigation; 7) Develop strategies to ensure implementation of 4(f) mitigation/project commitments.

The guidance manual and annotated list of court cases were converted to Adobe Acrobat format (Ver. 6.0). These provided a linkage function so users could navigate from the Table of Contents to both the Guidance Manual and the references in the Annotated List.

KTC-04-24/SPR268-02-1F "Safety and Health Concerns for KyTC and Contractor Personnel," Theodore Hopwood and Sudhir Palle, September 2004.

Abstract: This study was initiated to provide a review of safety and health issues related to Kentucky Transportation Cabinet (KyTC) construction activities including both KyTC and contractor personnel. Work included a literature search, interviews with KyTC resident engineers, and both a survey of and subsequent meeting with district construction safety coordinators. Recommendations are provided for implementing changes to improve safety and health regulatory compliance for both KyTC and contractor personnel.

KTC-04-30/SPR210-00-1F "Project Committment Follow-up," Theodore Hopwood and Sudhir Palle, December 2004.

Abstract: Three recently completed road construction projects were investigated to determine Kentucky Transportation Cabinet (KyTC) effectiveness in implementing project commitments (including environmental commitments). Documentation was obtained from KyTC districts in which

the projects were constructed and KyTC officials involved with the projects from planning through construction were interviewed. The projects were inspected to audit completion of project commitments. Key stakeholders (officials of local governments, resource agencies, MPOs, interest groups, and adjacent landowners) wre interviewed about the projects. They were asked to grade KyTC for implementation of project commitments using a standard report card format. The findings for these investigations are presented. The auditing procedure employed in this study can be used to rate future KyTC projects, identify problems, and suggest solutions.

FINANCIAL ANALYSIS

KTC-01-17/SPR99-192-1F **"State Road Fund Revenue Collection Process: Differences and Opportunities for Improved Efficiency," Robert J. Eger III and Merl M. Hackbart, July 2001.**

Abstract: Research regarding the administration and collection of road fund revenues has focused on gaining an understanding of the motivation for tax evasion, methods of evasion, and estimates of the magnitude of evasion for individual states. To our knowledge, little attention has been focused on the impact road fund collection, assessment, audit, and enforcement processes have on tax evasion. The purpose of this study is to review the current road fund assessment, collection, audit, and enforcement processes and procedures and to develop recommendations to improve the efficiency and effectiveness of the process.

KTC-02-11/SPR255-02-1F **"Transportation Finance: Kentucky's Structure and National Trends," Dr. Merl Hackbart, Suzanne Perkins, and Miriam Fordham, March 2002.**

Abstract: Analyses were made of Road Fund tax charges in the 50 states during the past decade along with an analysis of Kentucky's current Road Fund tax structure and collection system including multi-state tax collection collaborations. A comparison of surrounding states tax system was made to determine those differences that may affect the competitive impact on Kentucky businesses. Tax collection from commercial carriers is complicated since the tax base is shared among the states of the carrier's operation. This study provides policy makers and analysts with a comprehensive primer on Kentucky's tax structure and the emerging issues. A series of suggestions are provided that may enhance the adequacy, equity, administrative efficiency, and the competitiveness of Kentucky's Road Fund tax structure. A major recommendation is for a comprehensive review to predict and evaluate crosscutting impacts previous tax law changes and the preparation of a "blueprint" for restructuring Kentucky's Road Fund to insure fairness, adequacy, competitiveness and efficiency.

GEOTECHNOLOGY

KTC-01-07/SPR95-163-1F "Resilient Modulus of Kentucky Soils," Tommy C. Hopkins, Tony L. Beckham, Bixian Ni, and Charlie Sun, June 30, 2001.

Abstract: In recent years, the American Association of State Highway Transportation Officials (AASHTO) has recommended the use of resilient modulus for characterizing highway materials for pavement design. This recommendation evolved as of a result of trend in pavement design of using mechanistic models. Although much progress has been made in recent years in developing mechanistic pavement design models, results obtained are only as good as the material parameters used in the models. Resilient modulus of the subgrade soil is an important parameter in the mechanistic models and in the 1993 AASHTO pavement design equation. The main goal of this study was to establish a simple and efficient means of predicting the resilient modulus of any given type of Kentucky soil. To accomplish this purpose, 128 tests were performed on several different soil types from various locations of Kentucky. Specimens were remolded to simulate compaction conditions encountered in the field. Tests were performed on soaked and unsoaked specimens so that an assessment could be made of the affect of moisture on resilient modulus values. Vast differences were found between soaked and unsoaked values of resilient modulus.

Based on an analysis of the data, a new mathematical model is proposed which relates resilient modulus to any given selected, or calculated, principal stresses in the subgrade. This model improves the means of obtaining best data "fits" between resilient modulus and stresses. Furthermore, if the AASHTO classification and group index are known, than the resilient modulus of the soil can be predicted from the new model for any known stress condition in the subgrade. regression analysis was used to obtain relationships between resilient modulus and confining stress No difficulties were encountered in testing "as-compacted" (unsoaked) samples. Difficulties were encountered in testing soaked specimens. More research is needed to test saturated, or nearly saturated, soil specimens – conditions that often exist in the field.

To make the resilient modulus data and the new model readily available to design personnel of the Kentucky Transportation Cabinet, a "windows" computer software application was developed. This program is embedded in the Kentucky Geotechnical Database, which resides on a Cabinet server in Frankfort, Kentucky. The resilient predictor model and data are readily available to pavement design personnel statewide.

KTC-02-19/SPR196-99-1F "Long Term Benefits of Stabilizing Soil Subgrades," Tommy C. Hopkins, Tony L. Beckham, Charlie Sun, Bixian Ni, and Barry Butcher, June 2002.

Abstract: Chemical admixtures have been used extensively since the mid-eighties in Kentucky to improve bearing strengths of soil subgrades. Most pavements in Kentucky are constructed on clayey soils. Although short-term observations at a small number of sites showed that chemical stabilization worked very well. There was a need to perform a more comprehensive review and to assess the long-term benefits of this subgrade stabilization method. The main intent of this study was to address questions concerning bearing strengths, longevity, durability, structural credit, economics, and performance of pavements resting on soil subgrades mixed with chemical admixtures. In-depth field and laboratory studies were performed at fourteen roadway sites containing twenty different treated

subgrade sections. Ages of the sites range from about 8 to 15 years. About 455 borings were made at the various sites. Air, instead of water, was used at the drilling media. In-situ CBR tests were performed on the treated subgrades and the untreated subgrades lying directly below the treated layers. Index tests and resilient modulus tests were performed on samples collected from the treated and untreated subgrades. Falling weight deflectometer (FWD) tests were performed. At the 85th percentile test value, the in situ CBR values of subgrades mixed with hydrated lime Portland cement, a combination of hydrated lime and Portland cement, and a byproduct (MKD) obtained in the production of hydrated lime were 12 to 30 times greater than in CBR values of the untreated subgrades. In-situ CBR values of the treated layer ranged from 24 to 59 while the in situ CBR of the untreated layer at the 85th percentile test value was only 2. Based on rating criteria of the Kentucky Transportation Cabinet, the conditions of the pavements at twelve sites could be rated "good" at the time of the study – pavement ages were 8 to 15 years and "good" at the end of the twenty-year design period, based on projected data. At two sites, thin asphalt overlays had been constructed after 15 years. However, accumulated values of ESAL at those sites has exceeded or were near the values of ESAL assumed in the pavement design. At the 20th percentile test value, rutting depths of the pavements resting on the treated subgrades were less than about 0.27 inches. Structural layer coefficients for use in pavement design of the different chemically stabilized subgrades were developed. The proposed values were verified at sites where reduced pavement thickness was used and "in service" structural coefficients could be observed. Back-calculated values of FWD modulus of the treated layers were about two times the values of modulus of the untreated subgrade. Resilient modulus of the treated subgrades was larger than the resilient modulus of the untreated subgrades.

Moisture contents at the top of the untreated subgrade layers showed that a "soft" layer of material exists at the very top of the untreated subgrade. This soft zone did not exist at the top of the treated layer. This discovery has significant engineering implications. Future research will focus attention on an in-depth examination of this weak layer of soil. Chemical admixture stabilization is a good, durable and economical technique for improving subgrade strengths.

KTC-03-06/SPR177-98-1F **"Highway Rock Slope Management Program," Tommy C Hopkins, Tony L. Beckham, Charlie Sun, and Barry Butcher, February 2003.**

Abstract: Development of a comprehensive geotechnical database for risk management of highway rock slope problems is described. Computer software selected to program of the geotechnical database, and some of the primary factors considered in constructing the database are discussed. Major integrated components of the database include rock slope, landslide, and soil and rock engineering data. This report focuses on the rock slope component. The rock slope database program provides procedures for gathering field data and rating the hazardous conditions of rock slopes. Secondary components of the database include statistical analyzers and engineering applications for performing "on-line" analysis of data, developing correlations between different soil parameters, and performing engineering analysis and designs. Procedures for including historical soil and rock engineering data have been developed and programmed. Issues concerning database security, engineering units, and storing and displaying maps, graphics, and photographs are explored. The database contains procedures for dynamically overlaying the locations of landslides, rock slopes, and borings onto embedded roadway and digitized geological maps. Latitudes and longitudes of rock slopes and landslides were determined using Global Positioning System equipment. Strategies and illustrations of graphical user interfaces for data entry and retrieval are discussed. About 2086,

potentially hazardous rock slopes were rated numerically using the Rock Fall Hazard Rating system developed by the Oregon Department of Transportation and sponsored by the Federal Highway Administration (FHWA). A priority list of hazardous rock slopes can be generated rapidly.

KTC-03-07/SPR176-98-1F "Development of a Statewide Landslide Inventory Program," Tommy C. Hopkins, Tony Beckham, Charlie Sun, Bixian Ni, and Barry Butcher, February 2003.

Abstract: Development of a comprehensive geotechnical database for risk management of highway landslide problems is described. Computer software selected to program of the geotechnical database, and some of the primary factors considered in constructing the database are discussed. Major integrated components of the database include landslide, rock slope, and soil and rock engineering data. This report focuses on the landslide component. The landslide database module provides programmed procedures for gathering field data and rating the severity of landslides. Secondary components of the database include statistical analyzers and engineering applications for performing "on-line" analysis of data, developing correlation between different soil parameters, and performing engineering analysis and designs. Procedures for entering historical soil and rock engineering data have been developed. Procedures for entering and retrieval of landslide and rock slope data have been developed. Issues concerning database security, engineering units, and storing and displaying maps, graphics, and photographs are explored. The database contains procedures for dynamically overlaying the locations of landslides, rock slopes, and borings onto embedded roadway and digitized geological maps. Latitudes and longitudes of rock slopes and landslides were determined using Global Positioning System equipment (sub-meter accuracy). Strategies and illustrations of graphical user interfaces for data entry and retrieval are discussed. Some 1,400 highway landslides were identified and rated using a simple system devised by the University of Kentucky Transportation Center and the Kentucky Transportation Cabinet.

KTC-05-01/SPR270-03-1I "Swelling Pavement: Ky 499 Estill County," Tony L. Beckham and Tommy C. Hopkins, March 2005.

Abstract: A field and laboratory investigation was performed to determine why excessive swelling was occurring on a pavement section of KY Rouge 499 that was about four years old. Swelling occurred on a section of roadway that had been constructed with a hydrated lime-stabilized subgrade. As shown by laboratory swell tests, swelling of the pavement was due to the absorption of water and expansion of the compacted clay shale subgrade. Results of laboratory swell tests showed that the hydrated lime stabilization of the shale actually reduced swelling. Chemical reactions between calcium, present in the hydrated lime, and sulfates, which were present in small amounts did not contribute to swell.

KTC-05-03/SPR227-01-1F "Kentucky Geotechnical Database," Tommy C. Hopkins, Tony L. Beckham, Liecheng Sun and Bill Pfalzer, March 2005.

Abstract: Development of a comprehensive dynamic, geotechnical database is described. Computer software selected to program the geotechnical database, and primary factors considered in

constructing the database are discussed. Oracle ®8i, PowerBuilder ®8, and Map Object ® software were used to construct the database, build graphical user interfaces (GUI),and embed roadway maps, respectively. Any number of users may use the database simultaneously. Twelve highway district offices and several central offices of the Kentucky Transportation Cabinet are connected to the database. Data may be entered and retrieved dynamically.

This report summarizes four studies and describes the integration of major components of the database. Components include rock slope, landslide, and soil and rock engineering data. The first two studies, conducted in the mid 1990's, focused on potential rock slope hazards and the development of the rock slope management system. The rock slope component of the database provides procedures for gathering field data and rating the hazardous conditions of rock slopes. About 2100 of about 10,000 observed rock slopes were classified as potentially hazardous and rated numerically using the Oregon DOT's Rock Slope Hazard Rating System. The third research study focused on landslides. The landslide database provides programmed procedures for gathering field data, rating the severity of a landslide, and describes a management system. About 1,400 landslides were identified and rated using a simple system devised by the University of Kentucky Transportation Center and the Kentucky Transportation Cabinet. Latitudes and longitudes of rock slope and landslide sites were determined using Global Positioning System equipment (sub-meter accuracy). Attributes, including JPEG-format photographs and latitudes and longitudes, of rated rock slope and landslide sites are stored in the comprehensive database. A priority list of hazardous rock slopes and landslides can be generated rapidly.

The fourth study focused on soil and rock engineering data generated during geotechnical investigations and testing. This report dealt more with developing specific database features, simplifying data entry schemes, and expanding retrieval capabilities and flexibilities. Information in this report is presented in three parts: rock slopes, landslides, and soil and rock engineering data, which reflects the historical accumulation of these components under separate studies. Several schemes for retrieving data and generating reports are described.

Secondary components of the database include statistical analyzers and engineering applications for performing "on-line" analysis of data, developing correlations between different soil parameters, and performing engineering analysis and designs. Procedures for entering historical soil and rock engineering data have been developed and programmed. Issues concerning database security, engineering units, and storing and displaying maps, graphics, and photographs are discussed. The database contains procedures for dynamically overlaying the locations of landslides, rock slopes, and borings onto embedded roadway and digitized geological maps. Strategies and illustrations of graphical user interfaces for data entry and retrieval are described.

KTC-05-04/SPR180-09-1F **"Examination of Economical Methods for Repairing Highway Landslides," Tommy C. Hopkins, Tony L. Beckham and Bixian Ni, April 2005.**

Abstract: The Kentucky Transportation Cabinet spends millions of dollars each year in the repairs of highway landslides. In previous research, and inventory of highway landslides showed that about 1440 landslides of various sizes exist on major roadways maintained by the Kentucky Transportation Cabinet. Moreover, emergency repairs can exceed one million dollars for large embankment failures. In many instances, drilled-in, or driven, railroad steel rails were frequently used as a stop-gap measure to halt landslide movements or those efforts were tried as a permanent solution. The use of rails to serve as a restraining structure was usually not successful when the height of fill exceeded

about 20 feet. The previous study also showed about 39 percent of the landslides were small and less than 20 feet in height. Cost estimates indicated that railroad steel rails, when drilled and socketed into bedrock, may be effective and economical when the embankment height is less than about 20 feet. This study has two major objectives. Because railroad steel rails are widely used, the development of a theoretical method of analyzing and predicting the success of rails that are drilled-in and socketed into bedrock was a major objective. To enhance this method and possibly extend the height that this technique may be used, theoretical equations were developed that include the use of lightweight backfill materials, such as geofoam, shredded tires, bundled tires, "red dog," and byproducts from coal-fired power plant. Backfill materials with different unit weights, and existing in a layered system, may be analyzed. To facilitate the use of the approach and make it widely accessible to Cabinet engineers, and as a second major objective, the theoretical algorithms were programmed in a windows computer program and stored in the Kentucky Geotechnical Database. The twelve highway district offices and main central offices of the Cabinet are connected to this data base. For a selected factor of safety, the program predicts the success of drilled-in rails so that the user may avoid using this technique when the factor of safety is not adequate to prevent failure. However, when failure is predicted using the unit weights of ordinary soil, or rock, backfill, the program shows the thickness of geofoam (or other lightweight material) necessary to increase the factor of safety to value greater than one. The program has been checked by comparing results with results obtained from a program written by KyTC. Several examples are performed to illustrate the use of the new computer program.

KTC-05-05/SPR228-01-1I **"Reduction of Stresses on Buried Rigid Highway Structures Using the Imperfect Ditch Method and Expanded Polysterene (Geofoam)," Charlie Sun, Tommy C. Hopkins and Tony L. Beckham, April 2005.**

Abstract: The study of earth pressure distribution on buried structures has a practical importance in constructing highway embankments above pipes and culverts. Based on Spangler's research, the supporting strength of a conduit depends primarily on three factors: 1. the inherent strength of the conduit; 2. the distribution of the vertical load and bottom reaction; and, 3. the magnitude and distribution of lateral earth pressures which act against the sides of the structure. Considering high fills above them and high earth pressures they may experience, rigid culverts are usually used underneath highway embankments. To reduce high vertical earth pressures acting on a buried structure, ultra-lightweight Geofoam will be placed above a culvert, at Russell County, KY. Before construction began, numerical analysis using FLAC 4.00 (Fast Lagrangian Analysis of Continua) had been performed to predict stresses on the culvert. Results of the analysis show that Geofoam has a significant effect in reducing vertical stresses above and below the culvert. There are areas of high stress concentrations at the top and bottom of the concrete culvert if no Geofoam was placed above the culvert. After placing Geofoam above the culvert, the concentrated stress at the top can be reduced to 28 percent of the stress without Geofoam. The high stress at the bottom of culvert can be reduced to 42 percent of the stress without Geofoam. Stresses on the two sidewalls of the culvert were observed to have no significant change in values with and without Geofoam.

INTELLIGENT TRANSPORTATION SYSTEM

KTC-00-5 **"Intelligent Transportation Systems Strategic Plan," Jennifer Walton, Monica Osborne, Jerry Pigman, and Joe Crabtree, June 2000. SPR-98-188**

Abstract: This report presents a strategic plan for Intelligent Transportation Systems (ITS) in Kentucky. The purpose of this Strategic Plan is to offer a vision for ITS in Kentucky and to identify key goals for each functional area of ITS. A mission, vision, and goals are presented for Advanced Rural Transportation Systems, Advanced Traveler Information Systems, Commercial Vehicle Operations, Advanced Traffic Management Systems, Advanced Public Transportation Systems, and Advanced Vehicle Safety Systems. Also included is an inventory of existing ITS projects in Kentucky. Some of the fundamental elements of achieving the ITS vision are presented and discussed, including public relations and marketing, operations and maintenance, and organizational structure.

This plan serves as the foundation for development of a Statewide ITS Architecture and an ITS Business Plan.

KTC-01-14/SPR233-00-1F **"Management and Effective Use of Changeable Message Signs," Jennifer Walter, Monica Barrett, and Joe Crabtree, June 2001**.

Abstract: Changeable message signs (CMS) are used to communicate accurate, timely, and pertinent information to travelers on Kentucky's roadways. This information helps travelers avoid hazards or delays and respond properly to changing roadway conditions. In an ideal environment, the Kentucky Transportation Cabinet (KyTC) would be able to allocate CMS to various areas of the state based upon changing needs. The location of each sign would be monitored, and the message could be controlled and checked remotely.

Currently these capabilities do not exist. KyTC has four different types of portable CMS in use throughout the state. Each type has different internal and external interfaces, and each requires different replacement parts. Also, there is no policy or guidelines in place for the use of these signs. The decision on how and when the CMS are used is made at the district level on a case-by-case basis.

This research effort includes an evaluation of Kentucky's current inventory and usage of CMS, identification of key issues associated with the signs, and identification of state and regional policies on the management and use of CMS. Recommended guidelines for the management and use of CMS are included in this report.

KTC-02-03/SPR252-01-1F **"Evaluation of 220 MHz Frequencies for ITS Experimentation," David Q. Hunsucker, February 2002.**

Abstract: The Kentucky Transportation Cabinet implemented a 220 MHz wireless communication system as part of the TRIMARC traffic management system. The purpose of this research effort was to evaluate the use of the 220 MHz system to transmit data collected at the roadside to an operations center to enable operators to make sound decisions regarding traffic flow within the greater metropolitan area of Louisville, Kentucky. The attributes of the 220 MHz communication system,

relative to functional reliability and cost effectiveness of the system were evaluated to determine if further use of 220 MHz technology for ITS application is warranted.

The performance of the 220 MHz system has, by all accounts, been superb. The reliability of the system has been excellent when compared with conventional phone line service. The 220 MHz system has also proven to be extremely cost effective. The cost data obtained for this study indicated significant cost savings over the life of the project and recouping the initial extra investment practically within the first year after installation.

KTC-01-23/SPR188-98-1F "Intelligent Transportation Systems Business Plan," Jennifer Walton, Monica Barrett, Joe Crabtree, and Jerry Pigman, August 2001.

Abstract: This report presents a Business Plan for Intelligent Transportation Systems (ITS) in Kentucky. The purpose of the Business Plan is to define ITS projects that are planned for implementation from 2002 through 2007. The list of projects contained within this document was developed using Kentucky's ITS Strategic Plan, the ITS National Architecture, and stakeholder input.

There are 21 projects planned for implementation over the next 6 years at a total estimated cost of nearly $80 million. Another five projects will be considered when the Business Plan is updated in two years. These projects cover a wide range of topics including: traffic management, traveler information, public transportation management, commercial vehicle operations, emergency management, and information management. They will be implemented in all 12 highway districts across the state.

KTC-03-08/SPR188-98-2F "Intelligent Transportation Systems Statewide Architecture," Joseph D. Crabtree and Jennifer R. Walton, March 2003.

Abstract: This report describes the development of Kentucky's Statewide Intelligent Transportation Systems (ITS) Architecture. The process began with the development of an ITS Strategic Plan in 1997-2000. A Business Plan, developed in 2000-2001, translated the goals of the Strategic Plan into specific project recommendations. To develop the Statewide Architecture, the project team first inventoried all existing and planned ITS projects in the state. A project architecture was developed for each identified project, and these project architectures were then merged to form the Statewide Architecture. This report describes the background work that set the stage for the architecture, the actual architecture development process, and some of the key issues and challenges faced during the development. In addition this report provides a description of the actual deliverables that resulted from the architecture development.

KTC-04-14/SPR241-02-1F "Maintenance and Operations Plan for ITS in Kentucky," Jennifer Walton and Joe Crabtree, June 2004.

Abstract: This report presents a Maintenance and Operations Plan for Intelligent Transportation Systems (ITS) in Kentucky. It was developed using substantial stakeholder input and provides

recommendations and specific strategies for supporting and coordinating ITS maintenance and operations activities throughout the Kentucky Transportation Cabinet.

A literature review and national survey helped to identify other states and urban areas that had already completed work on ITS maintenance and operations. From this information, best practices were developed that represented the lessons learned and practices implemented (or suggested for implementation) by these states. Another survey was conducted to determine the current state of ITS maintenance and operations in Kentucky. In addition, a stakeholder forum was held to identify problems and potential solutions related to ITS maintenance and operations. The following tasks were accomplished as part of this project: a literature review and national survey; development of best practices; assessment of current operations; a stakeholder forum, and a development of the ITS maintenance and operations plan are included in this report.

Based on the best practices, Kentucky's ITS maintenance and operations assessment survey, and data from the stakeholder forum, 41 specific recommendations were developed. These recommendations were organized into the following categories: planning/management of maintenance and operations; coordination and communications; documentation, tracking, monitoring, and evaluation; procurement; staffing; training; facilities and equipment; funding; and contracting.

PAVEMENTS AND MATERIALS

KTC-00-18 **"Revision of the Rainfall Intensity Duration Curves for the Commonwealth of Kentucky," Bernadette Dupont and Dave Allen, March 2000. SPR98-178**

Abstract: The purpose of this study was to revise and update the existing Rainfall Intensity-Duration-Frequency (IDF) Curves for the Commonwealth of Kentucky. The nine curves that currently govern Kentucky are based on data from First-Order Weather Stations in and around Kentucky. However, the new curves only utilize data from within the State. The data was gathered from both First Order and Co-operative Weather Stations. In accordance with Bulletin 71, the new curves reflect the climatological zones located within the state, thus producing only four IDF curves.

KTC-01-19/SPR216-00-1F **"Development and Proposed Implement of a Field Permeability Test and Asphalt Concrete and Aggregate Base," David B. Schultz, Jr., John Fleckenstein, and David Allen, July 2001.**

Abstract: An air-induced field permeameter was developed in this study to measure the permeability of asphalt pavements. This device was correlated with a water permeameter developed by the National Center for Asphalt Technology. An attempt was also made to correlate the device with a laboratory permeameter developed by the Florida Department of Transportation; however, that attempt was not successful. Some of the conclusions of this study include:

- The air-induced permeameter (AIP) works well for measuring pavement porosity (permeability) and usually requires less than one minute to obtain a reading.
- The water permeameter developed by the National Center for Asphalt Technology (NCATP) also is effective in measuring pavement permeability; however, on pavements with low permeability, this device requires an extensive amount of time.
- The laboratory permeameter used in this study could not be calibrated with either the NCATP or the AIP. Therefore, it appears that the laboratory permeameter does not give a good description of field permeability.
- There was a good correlation between the NCATP and the AIP.
- Density has a highly significant influence on permeability. It appears that at approximately 92 percent of maximum theoretical density there is a dramatic decrease in field permeability.
- There is a wide variation in permeability across an asphalt mat. The lowest permeability nearly always occurs in the center of the lane with the highest permeability occurring at the construction joint.
- It appears the mean field permeability can be "estimated" from the aggregate gradation.
- It appears that any gradation, regardless of the nominal top-size aggregate can be designed for either a "low" or a "high" permeability.

KTC-02-07/SPR197-99 & SPR218-00-1F **"The Cost of Construction Delays and Traffic Control for Life-Cycle Cost Analysis of Pavements," Brad Rister and Clark Graves, March 2002.**

Abstract: The objective of this report is to provide the Kentucky Transportation Cabinet a reliable approach to quantifying/calculating "Road User Cost" often referred to as total user delay costs. To meet this objective, this report is divided into three main sections. The first section summarizes the reviews of three relatively new computer programs that can be used to help quantify delayed traffic incurred by the presence of a work zone. From this review, one program was selected based on it's user friendliness and ability to define both quantity of delayed traffic and queue length. The second section compares actual field data to the output of the selected program to help determine the program's reliability/predictability in determining both quantity of delayed traffic and quene lengths. The last section summarizes typical hourly user cost rates by vehicle type (i.e.: vehicle operating costs, delay costs, and accident/crash costs) that have been used by other agencies. By combining output from the selected program, and these typical user cost rates, one may be able to determine the total user delay costs associated with a highway construction project.

KTC-02-10/SPR208-00-1F **"Compaction on the Longitudinal Construction Joint in Asphalt Pavement," John Fleckenstein, David Allen and David Schultz, March 2002.**

Abstract: The objectives of this study were to evaluate the level of compaction at the construction joint in HMA pavements on new and existing projects; to determine the level of water infiltration and segregation at the joint and its effect on joint performance; to determine the most promising joint construction methods around the nation and worldwide by

reviewing specifications, experiences, and construction practices for joint construction and the prevention of joint segregation; to develop specifications and construction methods to ensure the level of density necessary at the joint for proper performance; and to review special paving equipment (attachments) for improving densification for the unsupported edge.

Four methods of joint construction were evaluated in this study. These were the notched wedge (12:1), restrained edge, joint reheater, and Joint Maker. In addition, a number of joint adhesives were used. Some of the major conclusions and recommendations from the study included:

- Contractors are consistently achieving levels of density at or near the construction joint that are within three percent of the lane density. It is recommended that specifications by written that would require contractors to achieve that level of density at or near the construction joint.
- The reheater achieved the highest joint density of all the methods; however, only one short project was included in the study. The effects of reheating the mat could not be determined during construction, but will be evaluated during long-term monitoring.
- The restrained-edge method of joint construction achieved the second highest overall densities and statistically was significantly better than the conventional method of construction, The notched wedge only marginally improved densities overall, while the Joint Maker showed no improvement over conventional construction techniques.
- It is recommended that more projects be constructed using the restrained-edge method.
- It appeared the notched-wedge method produced the lowest permeabilities at the joint.
- Preliminary performance data indicate that all projects are currently performing well with projects having joint adhesives performing as well as, or better than, projects without joint adhesives. It is recommended that other projects be constructed using joint adhesives.

KTC-02-18/SPR220-00-1F "Movements and Settlements of Highway Bridge Approaches," Bernadette Dupont and David L. Allen, June 2002.

Abstract: This report is a discussion of the bridge approach settlement or movement problem that is so prevalent in the United States. An explanation and/or description is given of the causes of these movements as described in the literature. A discussion concerning the cost to highway agencies is also given. A review and discussion of current practices in the county is given. This includes construction practices on approach embankment foundations, the approach embankment itself, various types of approach slabs, types of abutments and end bents, and drainage around approach embankments and bridge ends. A survey of all 50 states was conducted to determine the problems and practices in those states. Those results are summarized in this report. Additionally, a survey was conducted of all 12 highway districts in Kentucky to determine the differences in practice among those districts. Those results are given in Appendix B. Finally, conclusions and recommendations on the apparent best practices are discussed.

KTC-03-05/SPR245-02-1I **"Analysis of Field Permeability and Laboratory Shear Stresses for Western Kentucky Parkway, Milepost 18.xxx to Milepost 25.xxx Caldwell-Hopkins Counties," David Allen, February 2003.**

Abstract: This report lists and discusses results of field permeability tests and laboratory shear tests on samples from a construction project on the Western Kentucky Parkway in Caldwell-Hopkins counties. Approximately 6,500 tons of asphaltic concrete overlay placed on this project failed to meet minimum density requirements.

Field permeability tests were performed and the results showed that in areas where the mat failed to meet density requirements there was very high permeability in those locations.

The laboratory shear tests also showed that there was a direct relationship between shear strength and density. A linear elastic layer stress analysis also indicated that the shear strength of all of the laboratory tests specimens except one was less than the theoretical stresses that would occur under wheel loadings experienced in the field.

It was concluded that the overlay would probably have a shortened service due to the low densities which would possibly cause excessive raveling and rutting. It was recommended the material be removed and replaced.

KTC-03-20/SPR107-01-1I **"The Use and Performance of Geogrids in Kentucky," Aric Cowne, Richard Reitenour, David L. Allen and R. Clark Graves, August 2003.**

No report available.

KTC-03-32/SPR207-00-1F **"Evaluation and Analysis of Highway Pavement Drainage," Kamyar Mahboub, Yinhui Liu and David L. Allen, October 2003.**

Abstract: This report presents an analysis of pavement drainage using various finite element models. The analysis included a range of pavement materials and drainage parameters. The computational tool in study was the SEEP/W option in the GEOSLOPE computer program. A steady-state saturated flow analysis was employed to generate flow paths and flux quantities through the cross-sectional area of the pavement. Finite element models in this study covered various drainage practices and quantified their relative drainage advantages. Finally, recommendations were provided for optimum drainage practices as well as future research topics in this area.

KTC-04-22/SPR209-00-1F **"Optimization and Standardization of Pavement Management Processes," David Allen and Yuhong Wang, August 2004.**

No report available.

PLANNING AND SYSTEMS ANALYSIS

KTC-00-7 **"A Recommended Master Plan for the Kentucky Transportation Cabinet to Build a Partnership with the Public," Theodore Hopwood II, Donald G. Hartman, and Lenahan O'Connell, May 2000. SPR-98-185**

Abstract: Public involvement with proposed projects is necessary to facilitate their timely implementation by state highway agencies. New procedures are necessary to involve the public in the project development process and adequately address their concerns. Kentucky Transportation Center (KTC) researchers and Kentucky Transportation Cabinet Study Advisory Committee members cooperated to identify a set of recommended actions to be considered for implementation by the Cabinet. That work consisted of a series of "internal" reviews of problems and proposed solutions. That was supplemented by external reviews and interviews conducted by KTC researchers to identify "best practices" of other transportation agencies related to promoting public involvement and enhancing their public image.

The recommended master plan is comprised of four **Categories for Improvement**, with twelve *Principal Initiatives* (major goals) that are to be initiated by up to four *Key Action Steps*. The Master Plan is to be implemented in a relatively short three-year time frame. It is intended to support the Cabinet's adoption of context-sensitive design, to enhance the Cabinet's ability to involve the public and other stakeholders and to bring the Cabinet to a new level of environmental sensitivity and action.

KTC-01-04/SPR226-00-1F **"Richmond Public Transportation Study," Ted Grossardt, Len O'Connell, and Bruce Siria, June 2001.**

Abstract: This study focused on: 1) establishing the objectives for enhanced public transportation services in Richmond (KY); 2) quantifying likely demand; and 3) recommending a preferred service arrangement. It was concluded that the situation favored creation of a small deviated fixed route bus service in conjunction with the current demand response system. Several service scenarios were examined for optimizing the combined fixed and demand components of the system.

KTC-01-10/SPR219-00-2I "The Impact of a New Bypass Route on the Local Economy and Quality of Life," Eric Thompson, Joe Miller, and Jonathon Roenker, May 2001.

Abstract: The objectives of this research study were to assess the potential of a new bypass route to influence the overall growth rate of a local economy, the allocation of economic activity within the community, and overall community quality of life. To address these questions, we conducted a review of the literature, a statistical study of Kentucky counties that received a new bypass and similar counties within the state, and a case study of 8 bypass counties.

The findings were that a new bypass was not found to have a significant impact on employment and population growth in a community, although it could lead to a modest reduction in retail sales growth. A bypass was found to increase vacancy rates in the downtown area and to lead to a loss of retail-oriented businesses downtown and a concentration of retail-oriented businesses on the bypass. This process, however, was for the most part not driven by downtown businesses moving to the bypass, but rather by the location of new businesses along the bypass. Finally, while there were some concerns, surveyed residents of communities that received a bypass indicated that they felt that the bypass did not hurt business outside of the downtown area and that the bypass made contributions to the local quality of life, such as through reduced traffic congestion.

KTC-02-12/SPR221-00-1F "Enterprise Information System Analysis," Theodore Grossardt, and Joel Brumm, April 2002.

Abstract: The goal of this project was to assist the Cabinet in improving the way data is gathered, maintained, and used in the Highway Information System (HIS). The procedure was to identify the critical uses of various data categories, the specific needs for that data, and how that matched up with how the data is handled currently. The end result is a database of metadata information about the HIS database itself. This will enable new users and those unfamiliar with the background of the HIS to easily locate information about how data was collected, how frequently it is updated, and the responsible parties for particular data types.

KTC-02-30/SPR256-01-1F "Roadway Rating Process," Doug Kreis, December 2002.

Abstract: This study had two goals: 1. Formulate a new method for generating roadway adequacy ratings; 2. Construct an appropriate data set and then test the method by comparing it to the results of the HPMS-AP method. The recommended methodology builds on the previous methodology, the HPMS-AP. However, the recommended differs from the HPMS-AP in that it incorporates crash data into the adequacy rating and increases the relative weight given to indicators of roadway safety for the appropriate functional classification of highways. The software for the proposed highway rating system is in a format that permits "what if" scenarios. The comparison of the proposed method with the HPMS-AP shows the former more effectively identifies the roads with inadequacies.

KTC-04-03/SPR263-02-1F "2003 Motor Carrier Survey," Ronald E. Langley and Ted Grossardt, February 2004.

Abstract: The goal of this study was to conduct a survey to evaluate usage and satisfaction with the KyTC's new program allowing motor carriers to credential vehicles and pay taxes via the internet. Specifically, the study was to examine how many Kentucky motor carriers took advantage of this capability, why they did or did not, what improvements could be made to the system, and what incentives could be offered or obstacles removed to entice more motor carriers to use it.

KTC-04-17/SPR263-03-3F "Kentucky Highway User Survey 2004," Ted Grossardt and Ronald Langley, June 2004.

Abstract: The purpose of this study was to continue the efforts begun in 1997 to monitor Kentucky public opinion regarding the quality of highway systems, including a portion to measure satisfaction with current drivers' license and registration renewal processes. Kentucky's 2004 public opinion is compared to data collected in previous years to gauge the state's progress.

KTC-04-28/SPR264-02-1F "State Traffic Volume Systems Count Estimation Process," Doug Kreis and Angie Quigley, October 2004.

Abstract: The Kentucky Transportation Cabinet has an immense traffic data collection program that is an essential source for many other programs. The Division of Planning processes traffic volume counts annually. These counts are maintained in the Counts Database (CTS), which contains over 20,000 separate station locations and some traffic counts from as early as 1963.

The Division of Planning currently collects traffic volume counts for all non-interstate routes on a revolving three-year basis. Years wherein actual counts are not performed are supplemented with estimates generated by a FORTRAN program. Estimates are projected using prior actual counts by weighted linear regression methods. If an actual count is performed during the fiscal year, this count then replaces the estimated count. These traffic volume counts, both actual and estimated, are compiled into the Traffic Volume System (TVS).

The focus of this project was to research potential estimating methods to fulfill the above mentioned requests and to analyze possible contributing factors to traffic volume counts such as traffic growth, population, and economic development.

STRUCTURES AND COATINGS

KTC-00-1 **"Ranking and Assessment of Seismic Stability of Highway Embankments in Kentucky," Kevin G. Sutterer and Issam E. Harik, February 2000. SPR-96-173**

Abstract: This report presents the findings of three independent studies under the same grant. These were (a) assess and rank highway embankments along priority routes in western Kentucky according to seismic stability, (b) assess the seismic stability of the approach embankment for the U.S. 51 Ohio River crossing near Wickliffe, Kentucky, and (c) evaluate the seismic stability of the U.S. 41 Ohio River twin spans north of Henderson, Kentucky. Seismic stability of bridge foundations was not a part of this study.

The highway ranking assessed over 400 embankments and delineated each as having high, moderate, or little risk of significant failure for both the 50 and 500 year events. For the 50 year event, 6 were designated as high risk, while 145 were designated as high risk for the 500 year event. The report recommends evaluation of all high risk embankments and any moderate risk embankments along particularly critical sections of roadway.

The US 51 bridge embankment assessment indicated a high risk of embankment failure for the 500 year event, and a moderate risk of some deformation requiring repair for the 50 year event. The findings suggested the need for an emergency repair plan in the event of either earthquake, and suggested a more detailed evaluation if a higher confidence about the risk of failure was required.

The US 41 bridge embankment evaluation indicated little to no risk of major liquefaction for the 50 and 500 year events. A factor of safety of about 1.0 was estimated for seismic slope stability of the embankment at the bridge abutments, but a detailed stratigraphic section was not possible due to limited project budget. There thus remains some uncertainty about the overall seismic slope stability. The factor of safety is not likely to be significantly less than 1.0. This is acceptable for

seismic loading, as a factor of safety of 1.0 implies some deformation of the embankment may occur, but the extent of damage should be repairable on relatively short notice.

KTC-00-9 **"GFRP, Reinforcement Concrete Bridge Decks," David Deitz, Issam Harik, and Hans Gesund, SPR-96-169**

Abstract: This report investigates the application of glass fiber reinforced polymer (GFRP) rebars in concrete bridge decks as a potential replacement or supplement to conventional steel rebars. Tests were conducted to determine the material properties of the GFRP reinforcement, and experiments were performed to study aspects of GFRP rebar placement in actual bridge decks. These included observation of GFRP rebar handling characteristics and worker response during construction. Load tests of full-scale reinforced concrete specimens were conducted to evaluate the characteristics of three reinforcing schemes: (1) an epoxy coated steel (ECS) reinforcing scheme; (2) a GFRP reinforcing scheme, and (3) a Hybrid reinforcing scheme combining GFRP and ECS rebars.

Results of the investigation showed that the moduli of elasticity in tension and compression for the GFRP rebars were approximately the same, but the ultimate strength in compression was 50% of the ultimate strength in tension. Several recommendations were made for construction and repair procedures for decks reinforced with GFRP rebars. Modifications are suggested to existing theoretical expressions for predicting ultimate shear strength and maximum crack width of GFRP reinforced concrete members.

The results of this study show that bridge decks reinforced with GFRP rebars satisfy the AASHTO specifications for strength. AASHTO's crack width requirements were not satisfied.

KTC-02-13/SPR200-99-1F **"Flexural Behavior of R/C Beams Strengthened with CFRP Sheets or Fabric," P. Alagueundramoorthy, I. E. Harik, and C. C. Chow, May 2002**

Abstract: The resistance to electro-chemical corrosion, high-strength to weight ratio, larger creep strain, fatigue resistance, non-magnetic and non-metallic properties of carbon fiber reinforced polymer (CFRP) composites offer a viable alternative to bonding of steel plates in repair and rehabilitation of reinforced concrete structures. The objective of this investigation is to study the effectiveness of externally bonded CFRP sheets or fabric in increasing the flexural strength of concrete beams. Four-point bending flexural tests are conducted up to failure on nine concrete beams strengthened with different layouts of CFRP sheets and fabric, and three beams with different layouts of anchored CFRP sheets. An analytical procedure, based on compatibility of deformations and equilibrium of forces, is presented to predict the flexural behavior of beams strengthened with CFRP sheets and fabric. Comparisons are made between the test results and the analytical calculations.

Results of the testing showed that the flexural strength is increased up to 40% on beams strengthened with two layers of CFRP fabric, 49% for beams strengthened with two 1.42 mm thick CFRP sheets, and 58% on beams strengthened with two anchored 4.78 mm CFRP sheets.

KTC-02-14/SPR200-99-2F **"Shear Strength of R/C Beams Wrapped with CFRP Fabric," P. Alaguendramoorthy, I. E. Harik, and C. C. Choo, May 2002.**

Abstract: The emergence of high strength epoxies has enhanced the feasibility of increasing the shear strength of concrete beams by wrapping with carbon fiber reinforced polymer (CFRP) fabric. The objective of this investigation is to evaluate the increase in shear strength of concrete beams wrapped with different configurations of CFRP fabric. Shear tests are conducted up to failure on two reinforced concrete control beams and twelve reinforced concrete beams wrapped with four different configurations of CFRP fabric. An analytical procedure is presented to predict the shear strength of beams wrapped with CFRP fabric. Comparisons are made between the test results and the analytical calculations. The shear strength is increased up to 33% on concrete beams wrapped with CFRP fabric at an angle of $\pm 45^{\circ}$ to the longitudinal axis of the beam.

KTC-03-16/SPR269-03-1F "Survey of Welding Processes," Theodore Hopwood, July 2003.

Abstract: The current KyTC "SPECIAL PROVISION NO. 4 WELDING STEEL BRIDGES," prohibits the use of welding processes other than shielded metal arc welding (SMAW) and submerged arc welding (SAW). Nationally, bridge welding is codified under ANSI/AASHTO/AWS D1.5M/D1.5:2002 Bridge Welding Code. That document allows the use of other welding processes including flux core arc welding, gas metal arc welding, electroslag welding and electrogas welding after passing qualification tests.

Both the KyTC Special Provision and the Bridge Welding Code were reviewed. Representatives from 14 state highway agencies, fabrication shops, universities and welding equipment firms were questioned regarding the wider use of the welding processes allowed by the Bridge Welding Code but prohibited by the KyTC Special Provision. Based upon those responses, recommendations are provided to KyTC for updating the Special Provision and more fully adopting the Bridge Welding Code.

KTC-03-19/SPR215-00-1F "Reinforcement Alternatives for Concrete Bridge Decks," Chris Hill, Choo Ching Chiaw and Issam Harik, July 2003.

Abstract: This report investigates the application of various reinforcement types in concrete bridge decks as potential replacements or supplements to conventional steel reinforcement. Traditional epoxy coated reinforcement (ECS), stainless steel clad (SSC) reinforcement, MMFX microcomposite reinforcement, and carbon fiber reinforced polymer (CFRP) reinforcement were evaluated. Tests were conducted to determine the material properties of each reinforcement type.
Full-scale two-span reinforced concrete deck specimens were load tested to evaluate their performance.

CFRP reinforcement was deployed in a single-span bridge located on Elkin Station Road in Clark County, Ky. The SSC and MMFX reinforcements were each placed in a separate span in a two-span bridge located on Galloway Road in Scott County, Ky.

Results of the laboratory investigation showed that bridge decks reinforced with ECS, SSC, MMFX, and CFRP reinforcements satisfy the AASHTO Specification strength requirements.

KTC-04-20/SPR179-98-1F "Evaluation of the Service Performance of Bridge Components," Theodore Hopwood, Robert Brown, and Sudhir Palle, August 2004.

Abstract: This study was initiated to provide review of common bridges to determine the performance of their components. Seven bridge types were selected that constituted 85% of the Kentucky Transportation Cabinet (KTC) researchers, representing about 5% of those bridges. Common details/components were identified and evaluated including features of interest to the KyTC Study Advisory Committee. In addition to those findings, KTC

researchers evaluated KyTC National Bridge Inventory reports and maintenance needs forms for the same bridges.

Design modifications/material changes were recommended to improve performance of new bridges. Additionally, remedial measures were identified that would enhance the durability of existing bridges. Recommendations were also provided that would permit a more proactive approach to bridge maintenance activities.

TRAFFIC AND SAFETY

KTC-00-3 **"2000 Highway Cost Allocation Update," Monica Osborne, Jerry Pigman, Eric Thompson, March 2000. SPR-00-214**

Abstract: This update of the highway cost allocation study is the ninth in a recent series that began in the early 1980's by the Kentucky Transportation Cabinet and the Kentucky Transportation Center. The primary objectives are to determine the level of revenue contribution and cost responsibility for each class of highway user. The base year of this study is FY 1999; the most recent time period for which revenue and cost data are available. Highway user or travel activity for calendar year 1998 is the most recent available. A basic premise of the study is that only state maintained highways are of interest in recouping the costs expended to construct and maintain the system. In 1998, this system comprised 27,415 miles of the 73,360 miles of roads and streets in Kentucky, while accommodating 84 percent of all travel in the state.

There are 17 highway user classes with which revenue contribution and cost responsibility are associated. Primary sources of revenue include fuel taxes, registration fees, usage taxes, tolls, and other motor carrier and federal taxes and fees. Primary expenditure categories include construction (subdivided into 6 categories), maintenance and traffic, administration, and enforcement. Construction was subdivided into planning and design; right of way; utility relocation; grade, drain, and surfacing; resurfacing; bridges; and miscellaneous.

Results from the analysis indicate that cost responsibility is borne most heavily by cars and motorcycles with 44.06 percent; followed by heavy trucks with gross weights of 60,000 pounds or more at 27.06 percent. Pickups and other vehicles registered in the 6,000 pound category are responsible for 21.63 percent of the cost. The ratio of percentage revenue attributed to percentage cost allocated was also determined in the study. A ratio of one indicated that the revenue and cost percentages are in balance for a particular vehicle type. Cars (0.98), buses (0.86), and heavy trucks (0.90) contribute less revenue than their cost responsibility dictates.

KTC-00-4 **"Expansion of the Roadway Reference Log," Kenneth R. Agent, Joel Brumm, & Joel Weber, May 2000. SPR-99-201**

Abstract: The objectives of this study were to: a) expand the current route log to include milepoints for all intersections on state maintained roads and b) recommend a procedure for establishing milepoints and maintaining the file with up-to-date information.

Two types of output resulted from the study. One was an expanded route log computer file containing additional intersections between a state maintained and other public roads. The second output was a detailed procedure describing the method used to assign milepoints and a recommended procedure to maintain the file.

KTC-00-14 **"Safety Improvements for Two-Lane-Rural Roads," Kenneth R. Agent, Jerry G. Pigman, and Nikiforos Stamatiadis, July 2000. SPR-00-211**

Abstract: Two-lane rural roads in Kentucky have the highest fatal crash rate of any type of highway in Kentucky. This report is the first phase of a study with the objectives of: 1) identifying safety problems related to crashes on two-lane rural roads, 2) identifying high-crash locations, and 3) recommending possible improvements. The procedure used in this phase of the study involved an analysis of crash data to identify characteristics of crashes on two-lane rural roads, use of the crash data to identify one-mile sections having critical crash rates, and a review of countermeasures to start development of recommendations to reduce crashes on this type of highway.

KTC-01-01/SPR-219-00-1I **"Safety Impacts of Rural Road Construction," Kenneth R. Agent & Jerry G. Pigman, February 2001.**

Abstract: Crash data in Kentucky show that the fatal crash rate on two-lane rural roads is substantially higher than on any other type of road. Improvements have been proposed at some locations on this type of road which involve either upgrading the existing two-lane road or adding lanes resulting in a four-lane road. As part of the public information process, highway officials have been asked to document the previous results of this type of construction. The objectives of this study were to: 1) identify sections of two-lane rural roadways where either the two-lane road had been realigned and reconstructed or additional lanes had been added and 2) conduct a before-and-after analysis to determine how these changes affected traffic crashes.

Of the 49 locations included in the study, 25 involved adding lanes and converting to a four-lane road while the two-lane road was upgraded (realignment with wider lanes and shoulders) at 24 locations. Before the construction, the average traffic volume was almost three times higher on the roads where additional lanes were added than where the two-lane road was upgraded. The average daily traffic increased dramatically after the construction was completed with a slightly higher increase for roads where lanes were added.

When all the locations are considered, there was a 51 percent reduction in the crash rate when the road was upgraded and a 56 percent reduction in the crash rate when lanes

were added. The rate was reduced from 250 to 122 crashes/100 million vehicle miles (MVM) when the road was upgraded and from 258 to 114 crashes/100 MVM when lanes were added. When only the number of crashes in considered, the number of crashes per mile decreased by 39 percent when the road was upgraded and by 45 percent when lanes were added. The rate of injury or fatal crashes was reduced by 54 percent for upgrading the road and 55 percent by adding lanes while the number of crashes per mile decreased by 43 percent both when the road was upgraded and when lanes were added.

The overall conclusion of the study is that both upgrading two-lane rural roads and converting the road to four lanes are effective methods of reducing total crashes and injury or fatal crashes. The traffic volume would determine the appropriate alternative.

KTC-01-11/SPR211-00-2F **"Countermeasures for Fatal Crashes on Two-Lane Rural Roads," Kenneth R. Agent, Jerry G. Pigman, and Nikiforos Stamatiadis, May 2001.**

Abstract: A detailed analysis was conducted for a random sample of 150 fatal crashes which occurred on a two-lane rural road. A site visit was made to each crash location with data obtained and analyzed.

Recommendations were made for countermeasures to reduce the number and severity of crashes on this type of roadway. The countermeasures were divided into the general categories of roadway and non-roadway with the non-roadway divided into the areas of legislation, enforcement, and education/training. The roadway countermeasures did not include those involving roadway reconstruction. A recommendation was made that several of the countermeasures could be combined as part of a typical resurfacing project. The potential effectiveness of these countermeasures in preventing the crashes or reducing their severity was evaluated.

KTC-01-15/SPR213-00-1F **"Analysis of Traffic Growth Rates," Jerry G. Pigman, December 2001.**

Abstract: The primary objectives of this study were to determine patterns of traffic flow and develop traffic growth rates by highway type for Kentucky's system of highways. Additional subtasks included the following: 1) a literature search to determine if there were new procedures being used to more accurately represent traffic growth rates, 2) development of a random sampling procedure for collecting traffic count data on local roads and streets, 3) prediction of vehicle miles traveled based on socioeconomic data, 4) development of a procedure for explaining the relationship and magnitude of traffic volumes on routes functionally qualified as collectors and locals, and 5) development of county-level growth rates based on procedures to estimate or model trends in vehicle miles traveled and average daily traffic.

Results produced a random sampling procedure for traffic counting on local roads which were used as part of the effort to model traffic growth at the county level in Kentucky. Promising results were produced to minimize the level of effort required to estimate traffic volumes on local roads by development of a relationship between functionally classified collector roads and local roads. Both regression and logarithmic equations were also

developed to explain the relationship between local and collector roads. County-level growth rates in traffic volumes were analyzed and linear regression was used to represent changes in ADT to produce county-level growth rates by functional class. Linear regression and Neural Networks models were developed in an effort to estimate interstate and non-interstate vehicle miles traveled.

KTC-01-27/SPR199-98-1F **"Improving Incident Management Response and Coordination of Resources," Jennifer R. Walton, Monica L. Barrett & Jerry G. Pigman, October 2001.**

Abstract: Highway crashes cause a major impact to the transportation network by critically limiting the operational efficiency of the roadway. Traveler delay is the problem most often associated with highway crashes, but by far the most serious problem is the resulting secondary crashes that occur. Another related issue is the danger posed to response personnel serving the public at the scene. The magnitude of these problems is severe. A coordinated plan for managing the scene is needed to reduce the impact of highway crashes and improve the safety for everyone.

A Checklist and interagency workshop has been developed to address ways to secure and coordinate the resources necessary to restore the roadway's operation in a safe and timely manner. This Checklist and workshop serve as a reminder to responding agencies of the activities that need to be performed and who needs to perform them. A highway crash scenario activity is part of the workshop and helps all the agencies involved at a crash scene to gain a better understanding of each other's roles.

After the first workshop, 30 participants evaluated the Checklist and workshop. Ninety percent agreed that the workshop was helpful to them personally, and nearly 97% said they would encourage others to attend the workshop. Nearly 80% said they would use the Checklist on scene. Comments reflected that the interagency training was beneficial to them because it promoted communication and better understanding of everyone's role at a crash scene.

KTC-02-04/SPR249-02-1F **"2001 Traffic Safety Issues Opinion Survey," Kenneth Agent, Jerry G. Pigman, February 2002**

Abstract: As a means of determining public opinion on specific traffic safety issues, a public opinion survey was conducted. The survey consisted of a mail survey sent to 4,500 licensed drivers. Opinions on such issues as a primary seat belt law, prohibiting cell phones while driving, more regulation of truck driver training, and changes to the current graduated driver license program were obtained.

The most support was for legislation which would regulate training at commercial truck driving schools and would require the state to administer all tests for a truck driver to obtain a commercial drivers license. There was also strong support for designating funds to be used for high school driver education, requiring motorcyclists to wear a helmet, retesting high risk drivers, various changes to the graduated driver licensing procedure, prohibiting

riding in the bed of a pickup on public roads, and prohibiting the use of cell phones while driving.

KTC-02-05/SPR248-02-1F **"Investigation of the Impact of Large Trucks on Interstate Highway Safety," Kenneth R. Agent and Jerry G. Pigman, February 2002.**

Abstract: This study concentrated on the impact of large trucks on interstate highway safety. The objectives of this study were to investigate the impact of trucks on interstate travel and offer recommendations for improving safety. The procedure involved reviewing the literature, analyzing crash data, discussing the existing situation with the truck industry, and using the information to develop a list of countermeasures to reduce the number and severity of truck crashes on interstates. The countermeasures were grouped into the general areas of: a) the roadway environment, b) the truck, and c) the driver. The crash data were also analyzed to identify spots and sections on the interstate which had the highest number and rate of truck crashes.

KTC-02-08/SPR231-01-1F **"Evaluation of High Traffic Crash Corridors," Eric G. Green and Kenneth R. Agent, March 2002.**

Abstract: The objectives of this study were to: a) determine a procedure to use to identify corridors in each highway district for which a detailed analysis of crash data should be conducted, b) develop a procedure to use to analyze the crash data and recommend countermeasures, and c) conduct a case study analysis for one selected corridor. A method was developed to select high crash corridors, by highway district. The procedure involved obtaining a list of routes in each district which traveled through more than one county, determining various attributes for each route, calculating a relative value for each attribute for each route, and developing a ranking method to select a route for each district.

After a specific corridor is selected in a highway district, the crashes should be analyzed based on both a corridor basis and a review of high crash locations.

KTC-02-09/SPR230-01-1F **"Safety Implications from Design Exceptions," Kenneth R. Agent, Jerry G. Pigman and Nikiforos Stamatiadis, March 2002.**

Abstract: The objectives of this study were to: a) summarize past design exceptions to document their frequency and reason for their use and b) determine if any adverse safety implications can be related to adopting design policies and practices related to design exceptions. The design exception file was obtained with data objected relating to the types of project, exceptions requested, and the reasons for the various exceptions. A site visit was made to a large number of the locations where the project was built with the requested design exception with crash data obtained at most of these locations. The majority of the projects involved a bridge replacement followed by a roadway widening reconstruction project and construction of a turning lane. The most common design exception was for a design speed

lower than the posted speed limit followed by a reduction in either the sight distance, curve radius, or shoulder width. The most common reason referred to the existing conditions on the road followed by the right-of-way issue and project cost. The crash analysis showed that, with very few exceptions, use of the design exception process did not result in either construction of projects with high crash rates when compared to statewide average rates or an increase in crashes after compared to before construction.

KTC-03-09/SPR258-03-1I "Traffic Control at Stop Sign Approaches," Kenneth Agent, April 2003.

Abstract: The objectives of this report were to: a) determine the number of crashes in Kentucky involving a driver disregarding a stop sign and the locations where these occur, b) determine the characteristics of these crashes, c) investigate locations with a large number of this type of crash, and d) make recommendations to reduce the probability of a driver disregarding a stop sign. The majority of the analyses involved a review and analysis of crashes where a stop sign was listed as the traffic control and "disregarding the traffic control" was listed as a contributing factor. Intersections having a high number of this type of crash were identified with most of these intersections inspected. Using the results of the analysis, recommendations were made which could be considered to reduce the number of this type of crash.

KTC-03-12/SPR247-02-1F "Roadway Lighting and Driver Safety," Eric R. Green, Kenneth R. Agent, Monica L. Barrett, and Jerry G. Pigman, May 2003.

Abstract: The objectives of this project were to: a) analyze the safety benefits associated with roadway lighting; b) determine the design of the lighting installation necessary to provide an adequate level of lighting; c) investigate how lighting affects the driver and the roadway's surrounding environment; d) review the economic correlation between effective lighting and cost savings for the State; e) provide input for updating the current section on street and highway lighting in the Traffic Guidance Manual; and f) analyze crash data to identify nighttime high crash locations. The procedure involved a literature search, a survey of states, crash data analysis, and collection of illumination data.

The survey of states found that most states used information from either "An Informational Guide for Roadway Lighting" by AASHTO or "American Standard Practice for Roadway Lighting (ANSI/IESNA RP-8-00)" as a basis for their warrants and design of highway lighting. A procedure was developed to identify spots or sections that have a critical number or rate of nighttime crashes. An interactive nighttime critical rate analysis program was developed. Crashes at spots and intersections having a high number or rate of nighttime crashes were reviewed. A large number of the locations identified as having a high nighttime crash rate are rural locations where the nighttime crashes can be addressed with improved delineation (pavement markings and signage). The illumination data show that the AASHTO guidelines can be met with a limited number of properly located luminaires. For example, one luminaire placed across from the single approach at a "T-intersection" or two luminaries

on diagonal quadrants of a "cross-intersection" (adjacent to the side street stop approach) were found to meet the guidelines if properly located.

KTC-03-15/SPR250-02-1F **"Development of Procedures for Identifying High-Crash Locations and Prioritizing Safety Improvements," Kenneth R. Agent, Len O'Connell, Eric R. Green, Jerry G. Pigman, Neil Tollner, June 2003.**

Abstract: The objectives of this study were to review and analyze the current procedures for identifying high-crash locations and evaluating and prioritizing roadway safety improvements at high-crash locations, and to recommend improved methods. Several tasks were undertaken to accomplish these objectives, including the following:

- Review of program guidelines and procedures used by other states to prioritize improvements at high-crash locations
- Review and documentation of Kentucky's current procedure
- Update of Kentucky's Crash Buildup Program software to be compatible with the 2000 crash report form
- Development of new software to assist in estimating the benefits and costs of potential projects for inclusion in the Hazard Elimination Program
- Conversion of the dynamic programming software from mainframe to PC

Results from the study include improved methods for identifying high-frequency crash locations and prioritizing those locations after preliminary analyses indicated a need to consider improvements at a crash site. Software was developed to assist in producing a generalized estimate of the benefits of potential projects for inclusion in the Hazard Elimination Program. To use the software, the user must input the improvements to be made, the current level of crashes for highway segment, and estimated project costs. Adjustments can also be made for key factors such as discount rate and projected traffic growth. Features include a menu of types of improvement projects and related reduction factors, and benefit-cost comparisons for each project.

Revisions were recommended for updating and enhancing the Crash Buildup Program to achieve compatibility with the current crash data report form and for translating the dynamic programming module from a mainframe operation to a PC-based system. It appears that an increased level of functionality has been achieved as a result of the series of modifications and improvements.

KTC-03-21/SPR258-03-2I **"Crash Rates at Intersections," Eric R. Green and Kenneth R. Agent, August 2003.**

Abstract: The objectives of this study were to develop a database of intersections, match traffic crashes to these intersections, calculate crash rates for various types of intersections, and identify intersections with the highest crash rates. A procedure was used to: a) identify intersections, b) assign crashes to these intersections, c) determine entering traffic volume, d) calculate a crash rate for each intersection, and e) calculate a critical rate factor (CRF) for each intersection.

About 7,000 intersections were identified with almost 19,000 crashes related to these intersections for the three-year period of 2000 through 2002. The analysis identified 428 intersections that had a CRF of one or more while only 36 intersections had a CRF above two. As would be expected, the crash rates are higher in urban than in rural areas. In both rural and urban areas, the rate was highest for four-lane undivided highways and lowest for four-lane divided highways.

An Excel spreadsheet containing a list of all intersections of two or more state-maintained roadways was developed. The spreadsheet also contains crash and volume data for each intersection. The intersections with the highest critical rate factors can be identified. This list can be divided by highway district with the objective of investigating the intersections with the highest CRFs and determining if improvements should be implemented.

KTC-04-1/SPR107(4)98-2F "Evaluation of the ET2000 Guardrail End Treatment," Kenneth R. Agent, January 2004.

Abstract: The objective of this study was to report the results of the monitoring of the performance of the ET2000 guardrail end treatment in traffic crashes. This end treatment has an energy-absorbing design in which a vehicle will push a guardrail extruder back as posts designed to breakaway are broken. The W-beam guardrail is flattened as it goes through the extruder and exists a slot away from traffic.

Data for a total of 135 collisions involving the ET2000 were identified. A crash report was obtained in the majority of crashes and the damaged guardrail was inspected in almost all cases. The involved vehicle was inspected when available. Proper or improper performance of end treatments in the collisions were judged, when a policy report was available, based on whether it performed as designed.

Field performance of the ET2000, as documented in traffic crashes, shows that, considering all the impacts, this end treatment has performed properly. In some instances the end treatment bent, rather than being pushed straight back, during the collision. This could typically be related to the angle at which the impact occurred.

Results warrant continued use of this type of end treatment. However, its cost compared to other end treatments would not justify a widespread use on all types of highways.

KTC-04-2/SPR257-03-1F "Effect of Pavement Resurfacing on Traffic Safety," Kenneth R. Agent, Jerry G. Pigman, and Eric R. Green, February 2004.

Abstract: The objectives of this study were to analyze the before and after crash history and speeds on routes which have been resurfaced, inspect resurfacing projects, make recommendations to improve the resurfacing process, and determine improvements which could be made in conjunction with the resurfacing project to improve the overall safety of the roadway. An analysis of the before and after crash data did not find a reduction in total crashes after resurfacing. There was a reduction in crashes which occurred on wet pavement.

A comparison of speeds before and after resurfacing did not find a major change in travel speeds. Considering all locations, there was an average increase in speeds after resurfacing of less than one mph. Discussion with state inspectors and contractors found agreement of areas which could be changed to improve the resurfacing process. Most of the comments dealt with preparation of the road prior to paving, methods to place the shoulder, and the paving operation. Recommendations were made to consider when resurfacing roads. They were grouped into the following categories: preparation for resurfacing, shoulder-related issues, paving operation, and general issues.

KTC-04-5/SPR251-01-1F **"Access Management for Kentucky," Nick Stamatiadis, Barry House, Jeremy Brickey, Don Hartman, Mei Chen, Jerry Pigman, Kavita Boodu, Soni Patangay, and Emily Elwood, January 2004.**

Abstract: The objective of this research was to develop the foundation for an access management system in Kentucky. A review of practices in other states that have an established program was completed and allowed for the identification of the critical steps required for the development and implementation of an access management system. A new roadway classification system that is based primarily on highway functional classification has been proposed to form the basis for classifying roadway segments for establishing the allowable access level. A series of spacing requirements were also proposed using this classification system. Recommended practices and proposed steps for implementation of an access management program for Kentucky include the following: 1) form an implementation task force, 2) develop and execute a public involvement plan, 3) finalize spacing and design standards, 4) complete classification assignments and revisions, 5) develop an administrative regulation, 6) address non-conforming access, 7) develop variance procedure, 8) define appeal process, 9) define permitting process, 10) define organizational roles and responsibilities, 11) develop access management manual, and 12) conduct training on new program.

KTC-04-7/SPR278-03-1F **"2004 Highway Cost Allocation Update: Technical Report," Monica L. Barrett and Jerry G. Pigman, February 2004.**

No report available.

KTC-04-8/SPR276-04-1F **"Evaluation of the Accuracy of GPS as a Method of Locating Traffic Collisions," Eric R. Green and Kenneth R. Agent, May 2004.**

Abstract: The objectives of this study were to determine the accuracy of GPS units as a traffic crash location tool, evaluate the accuracy of the location data obtained using the GPS units, and determine the largest sources of any errors found.

The analysis showed that the currently used GPS unit is capable of obtaining accurate latitude and longitude data at a crash site that would allow the site to be properly located. However, substantial differences were found between the location of some crashes as identified with the GPS and milepoint (CRMP) data. Of a sample of 100 random crashes, 55 percent were found to have an accurate GPS reading and 58 percent were found to have an accurate CRMP location. There was a large range in the difference between the GPS and CRMP data by county and police agency. This shows both the accuracy that can be obtained with proper training and use as well as the lack of proper training and/or use of the GPS units at some jurisdictions. The source of errors found for the GPS data was related to the operator rather than the equipment or environment. The actions necessary to significantly improve the accuracy of the GPS data are manageable and relate to training, proper use of the GPS unit, care when placing the GPS data onto the crash report, and a minor modification to the crash report. The source of errors related to the CRMP data primarily dealt with improper interpretation of the milepoint log, inaccurate use of the available mileposts and lack of knowledge of current data available. A few edits of the crash data could be used which would significantly improve the accuracy of both the GPS and CRMP data.

Recommendations were made to improve the accuracy of both GPS and CRMP data. These included additions to the GPS procedure pamphlet, a minor modification to the crash report, additional training in the use of the GPS unit, providing up-to-date milepoint logbooks, and using an edit which checks the accuracy of the GPS and CRMP data.

KTC-04-11/SPR204-99-1F **"Context Sensitive Design - Thinking Beyond The Pavement Documentation of Workshop Development and Training," Jerry G. Pigman, Donald Hartman, Theodore Hopwood, Kenneth R. Agent and Len O'Connell, May 2004.**

Abstract: This report documents the development and presentation of the workshop titled "Thinking Beyond the Pavement - A Workshop on Context Sensitive Design". Work began on the workshop development in 1998 after the Kentucky Transportation Cabinet was selected as one of the pilot states to implement a training program for context sensitive design. The Kentucky Transportation Center at the University of Kentucky was selected to develop and deliver the training to state personnel and consultants who were commonly involved with project development. The training course was comprised of the following four modules:

- Facilitated Communication and Public Involvement,
- Environmental Issues,
- Liability Issues, and
- Design Guidelines, Safety, and Aesthetics.

A case study was prepared for use with the training modules in order to simulate the project development process and promote participant interaction. Through May 2004, there were 46 presentations of the workshop with 1,693 participants.

KTC-04-12/SPR258-03-3F **"U-Turns at Signialized Intersections," Nikiforos Stamatiadis, Teja Banu Kala, Kenneth R. Agent, May 2004.**

Abstract: The objectives of the study were to examine the safety consequences from the installation of U-turns at signalized intersections in Kentucky and to develop a set of guidelines for using this alternative in the future. The literature review indicated that the use of U-turns is very effective in reducing delays as well as crash rates. The most efficient configuration is that of stop-controlled median U-turns. An analysis of the crash data shows that the U-turn design in Kentucky locations did not result in a large number of crashes involving U-turning vehicles. Also, at the Somerset location where the design eliminated median crossovers between intersections, there was a decrease in total crashes. Potential factors that could affect the implementation of U-turns at intersections were examined. Using delay time as a measure of effectiveness, it was concluded that the presence of the U-turn enhances the operation of the corridor most likely due to the more efficient processing of vehicles at the downstream intersection. The study recommends that U-turns should be considered for corridors with peak volumes greater than 1,500 vph or for cases where the expected total turn volume is greater than 20 percent of the total approach volume.

KTC-05-02/SPR285-05-1F **"Review of Traffic Provisions of KRS/KAR and Kentucky Drivers Manual," Kenneth R. Agent and Jerry G. Pigman, March 2005.**

Abstract: This study included a review of selected sections of KRS and KAR that relate to traffic and safety. Also, the Kentucky Drivers Manual was reviewed. The review involved an evaluation of the applicability and consistency of these documents as well as their agreement with nationally recognized standards and guidelines.

Detailed comments were provided to the Kentucky State Police after a through review of the Kentucky Drivers Manual. An emphasis was placed on updating portions of the manual where traffic control devices were described, as well as a general update to conform with the Uniform Vehicle Code. Many of these recommended revisions were incorporated into the revised manual. Each section of KRS Chapter 189 and each chapter of KAR Title 601 and 603 were reviewed. Modifications or questions concerning various aspects of the legislation or regulations were identified for several sections or chapters. Members of the study advisory committee were requested to review and concur with the recommendations. All of the comments were then summarized and presented to the advisory committee for their comments and suggestions. A list of recommended revisions or modifications was prepared and reviewed, and approved by the committee.

KTC-05-08/SPR228-05-1F **"Development of Kentucky's Highway Incident Management Strategic Plan," Monica L. Barrett, Joseph D. Crabtree and Jennifer R. Walton, May 2005.**

Abstract: Even though Kentucky has undertaken many initiatives to improve specific aspects of incident management, there has never been a plan that establishes an overall framework for a systematic, statewide, multi-agency effort to improve the management of highway incidents. The objective of this project was to develop a strategic plan that provides

a vision and strategy for significantly improving all aspects of incident management. This report identifies the current and best practices for highway incident management in the United States and in Kentucky and establishes a vision for the future of highway incident management in Kentucky. The plan developed through the efforts of this project consists of a mission statement, 4 goals, 16 objectives, and 49 action strategies. The action strategies are arranged by priority and recommended time frame for implementation. When implemented, the action strategies will help Kentucky achieve its primary goals for incident management: 1) improved safety of responders, highway workers, and motorists; 2) reduced traffic delay; 3) improved motorist awareness; and 4) improved responder and highway worker preparedness.

KTC-05-09/SPR277-03-1F **"Evaluation of Auto Incident Recording System (AIRS)," Eric R. Green, Kenneth R. Agent and Jerry G. Pigman, May 2005.**

Abstract: The Auto Incident Recording System (AIRS) is a sound-actuated video recording system used to analyze the reasons for traffic crashes at intersections. I automatically records potential incidents when sound is recorded (horns, clashing metal, squealing tires, etc.). the purpose is to detect patterns of crashes at intersections in order to implement relevant improvements. The system consists of two video cameras located on two corners of the intersection to obtain a view of incidents and near-incidents from different perspectives, two directional microphones that listen for sounds that could be related to a traffic crash, digital signal processors and recording media, and a video cassette recorder.

Videos of incidents and near-incidents were obtained after AIRS was placed in service on July 22, 2001 at an intersection in Louisville, Kentucky. Crash reports were obtained from January 1998 through September, 2004 to compare to the available data from AIRS videos and to compare the crashes before and after various improvements were made.. The videos and police reports were reviewed and were categorized by type. A traffic conflict study was made at the intersection and the traffic conflict data was compared to results obtained from AIRS and to the crash summary.

It was found that AIRS is capable of documenting crashes at an intersection. AIRS data can be used as a reliable surrogate for crash data. The near-incidents identified by AIRS were very similar to the incidents recorded by AIRS and the crash report data. An excessive number of false incidents were recorded. A large number of crashes (47) occurred that were not recorded by AIRS with no explanation found to explain the failure for approximately one third of those crashes. The AIRS data were a more reliable surrogate of crash data than the conflict data.

AIRS provides a time efficient method of analyzing intersection collisions compared to a conflict analysis or a continuous videotaping. However, the efficiency is limited somewhat by the large number of false incidents found by AIRS. A method to minimize these false incidents should be developed. The improvements made as a result of the AIRS data resulted in a reduction in crashes at the study intersection. The crash savings in one year would pay for the cost of the AIRS installations. This shows that AIRS had a high benefit-Cost ratio. Given the costs and limitations of both AIRS and conflict studies, an alternative which should be considered is the completion of an intersection safety audit.

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