ENGINEERING AND MANAGEMENT EXPERIENCE AT TEXAS A&M TRANSPORTATION INSTITUTE

A Record of Study

by

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DOCTOR OF ENGINEERING

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ABSTRACT

This manuscript presents the author's engineering and management experience during his internship in the Materials and Pavements (M&P) Division at the Texas A&M Transportation Institute (TTI), and is a record of study for the Doctor of Engineering at Texas A&M University. Through this internship, he met his established internship objectives of gaining technical knowledge as well as knowledge and skills in project management, organizational communication, and quality management of pavement condition data, and of attaining professional development.

In meeting these objectives, the author describes the history, mission, and organizational structure of his workplace. He also presents his experience of developing and delivering a two-week training course on pavement design and construction in Kosovo. Participating in a number of professional development training courses and other activities prepared him for working as an engineering manager. These activities include Delta-T leadership training, an instructor development course, a time management and organizational skills course, and the M&P Division lecture series. Leadership and skills learned through the Delta-T program were beneficial for the employee as well as the employer. For the class project, the author and his teammates performed a study dealing with improving TTI's deliverables. The Delta-T team composed a report summarizing their efforts of examining the current state of TTI's project deliverables, the deliverables' shortcomings, and potential enhancements to expand the deliverables' appeal to additional types of potential users outside the

traditional research community. The team also developed a prototype web-based model of deliverables and presented some implementation recommendations.

Participating in the Texas Department of Transportation's (TxDOT's) pavement surface distress data collection program enabled the author to become familiar with pavement distress data quality management and thus attain the technical and nontechnical skills required for project management. He noticed some areas for improvement in TxDOT's rater's manual, rater's training class, and acceptance criteria for visual distress data.

DEDICATION

To my wife, Anindita Ahmed, whose patience, continuous inspiration, and support made this accomplishment possible, and to my parents, who always valued my education.

ACKNOWLEDGMENTS

I would like to thank my graduate advisor and committee chair, Dr. Eyad Masad, for his guidance, continuous encouragement, and support throughout my Doctor of Engineering program at Texas A&M University. I am especially grateful to my committee member, Dr. Roger Smith, for providing detailed guidance during the internship and coursework. I am also thankful to the other committee members, Dr. El-Halwagi and Dr. Gharaibeh, who have supported my participation in this program. I appreciate the guidance and supervision provided by my internship supervisor, Dr. Andrew Wimsatt.

Thanks also go to my colleagues at the Texas A&M Transportation Institute (TTI) for making my time at TTI a great experience. I also want to extend my gratitude to my teammates during Delta-T leadership training at TTI for a great team effort. Special thanks go to my former supervisor Mr. Joe Button for his mentorship and inspiration, and to Dr. Magdy Mikhail and Mr. Marlon McGhee for providing data and information.

NOMENCLATURE

AASHTO	American Association of State Highway and Transportation Officials
ACP	Asphalt Concrete Pavement
CRCP	Continuously Reinforced Concrete Pavement
DEng	Doctor of Engineering
DOT	Department of Transportation
FHWA	Federal Highway Administration
IAC	Interagency Agreement Contract
JCP	Jointed Concrete Pavement
M&P	Materials and Pavements
NCHRP	National Cooperative Highway Research Program
NHI	National Highway Institute
PI	Principal Investigator
PMIS	Pavement Management Information System
PMS	Pavement Management System
PSDDC	Pavement Surface Distress Data Collection
QC/QA	Quality Control/Quality Assurance
ROS	Record of Study
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation

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CHAPTER I

INTRODUCTION

This record of study (ROS) documents my 18 months of engineering research experience as an assistant research engineer with the Materials and Pavements (M&P) Division of the Texas A&M Transportation Institute (TTI). This ROS also serves as partial fulfillment of my degree requirement for the Doctor of Engineering (DEng) program at Texas A&M University. TTI, a state agency and a part of The Texas A&M University System, was established in 1950 in order to enhance the economic competitiveness of the state and improve the quality of life for Texans.

The engineering profession is a community activity and hence requires both technical and nontechnical knowledge and skills. Some examples of nontechnical knowledge and skills that are critical to engineers are communication skills, government/legal regulations, concern for public safety and the environment, project management, human resources management, basic accounting/budgeting/marketing, and engineering ethics. The DEng program offered at Texas A&M University, under the Dwight Look College of Engineering, provides an exceptional opportunity to pursue the highest level of engineering careers in industry, business, and the public sector. Wide varieties of courses from different relevant disciplines and industry internships prepare DEng candidates with the critical knowledge required to assume positions of authority and responsibility (Texas A&M University 2009).

Since my enrollment in the DEng program at Texas A&M University, I have completed required coursework selected from diverse disciplines. One of the requirements for this degree is completion of at least a one-year internship, with the general objective of enabling the student to apply knowledge and technical education in an area of practical concern to the organization in which the internship is served.

Internship Objectives

The objectives of this internship were to enhance my ability in project management, organizational communication, and quality management of pavement condition data, and to attain professional development. These objectives help fulfill TTI's mission of solving transportation problems through research, technology transfer, and the development of diverse human resources to meet the transportation challenges of tomorrow. Through the assignments described in this ROS, I became capable of handling various aspects of this organization rather than solving a specific technical problem.

Organization of Report

I worked on more than half a dozen projects during my internship period at TTI and describe a few of these projects in this ROS. The projects described in more detail here are those most closely related to my DEng internship objectives. I also prepared or assisted others in preparing proposals for funding, some of which were funded by the sponsors. I authored or coauthored several research reports and papers as well.

This ROS is organized into six chapters. Because of the personal nature of my experience at TTI, I decided to narrate my experience in the first person. Chapter I provides the introduction and my objectives set prior to the beginning of the internship. Chapter II describes TTI, its history, mission, organizational structure, and facilities. Chapter II also provides brief descriptions of additional research projects that I worked on besides the two major projects mentioned in later chapters. The emphasis of the narration in Chapter II is on the nontechnical and managerial experience I gathered from these research projects. These research projects include two studies sponsored by the National Cooperative Highway Research Program (NCHRP) and one study sponsored by the Texas Department of Transportation (TxDOT). Chapter III presents my experience during a training assignment in Kosovo. I developed and delivered a two-week training course on pavement design and quality control/quality assurance of highway construction in Kosovo. This project was sponsored by the U.S. Agency for International Development (USAID). Chapter IV includes the different professional development trainings, seminars, and other activities that I participated in. These activities included instructor development training offered by the National Highway Institute (NHI), Delta-T leadership training at TTI, and coordination of seminars and presentations by speakers from industries, agencies, and academia. This chapter also describes my efforts to enhance internal communications among the employees of the M&P Division at TTI. Chapter V describes my experience of working on a project where TTI provided third-party quality assurance for TxDOT's annual pavement distress data evaluation program. This project was carried out under an interagency agreement contract (IAC) between TxDOT and TTI. The final chapter provides a summary of my overall experience gained during the internship period and how I achieved the internship objectives and subsequent recommendations.

The Delta-T report *Evolving Our Research Deliverables*, which I co-authored, appears as an appendix of this ROS. This report summarizes the Delta-T team's effort to examine the current state of TTI's project deliverables, their shortcomings, and potential enhancements that could be made to expand their appeal to additional types of potential users outside the traditional research community. This report is also available on the TTI intranet.

CHAPTER II

TEXAS A&M TRANSPORTATION INSTITUTE

I completed my DEng internship at my current workplace, the M&P Division of TTI. I have been working as a full-time employee at this organization since 1999. This chapter will provide a brief description of TTI.

TTI is a part of The Texas A&M University System and is a state agency dedicated to transportation research. The institute has made significant advancements in transportation safety, mobility, planning, systems, infrastructure, the environment, and other areas vital to good quality of life.

TTI was established in 1950 in order to enhance the economic competitiveness of the state and improve the quality of life of Texans. In time, it became the world's largest university-based transportation research institute. Since its inception, TTI has sought solutions to the problems and challenges facing all modes of transportation. TTI has a breadth and depth of programs, facilities, and capabilities to address transportation-related issues. The institute participates on the local, state, regional, and national level in conducting interdisciplinary research programs that extend into the planning, design, construction, operation, maintenance, enforcement, safety, economic, ecological, and social aspects of transportation.

TTI maintains research divisions, research centers, field offices, and regional divisions. Research divisions include the Economics and Planning, M&P, Safety, Transportation Systems, Structural Systems, Systems Planning, and Traffic Operations

Divisions. TTI employs over 650 professionals, students, and support staff from over 30 different countries (Texas A&M Transportation Institute 2014). Major research areas include materials and pavements; safety; transportation systems; structural systems; systems policy, planning, and the environment; traffic operations; railroads; pipelines; and ports and waterways.

Under legal and administrative actions, TTI may contract to provide research services to other public agencies, private firms, and other international organizations. Although conducting research in the field of transportation is the core business of TTI, it can provide other engineering and technical services such as training, testing, and design to public agencies.

TTI's Mission

TTI's mission is "to solve transportation problems through research, to transfer technology, and to develop diverse human resources to meet the transportation challenges of tomorrow."

Locations

The headquarters of TTI is located on the campus of Texas A&M University in College Station. The institute maintains a full-service safety proving grounds facility; an environmental and emissions facility; a sediment and erosion control laboratory in Bryan, Texas; other facilities and laboratories on the Texas A&M University campus; and a test track in Pecos, Texas. TTI has eight urban offices in Texas—Arlington, Austin, Dallas, El Paso, Galveston, Houston, San Antonio, and Waco. TTI also has a presence in Mexico City and in Doha, Qatar, at Texas A&M University at Qatar (Texas A&M Transportation Institute 2013).

Besides different broad category divisions, TTI has the following research centers focusing on specific objectives:

- Center for Alcohol and Drug Education Studies,
- Center for International Intelligent Transportation Research,
- Center for Ports and Waterways,
- Center for Railway Research,
- Center for Transportation Computational Mechanics,
- Center for Transportation Safety,
- Southwest Region University Transportation Center,
- Transportation Economics Center, and
- Transportation Policy Research Center.

Organizational Structure

TTI

Dr. Dennis Christiansen has been the agency director of TTI since 2006. There are four executive associate directors and one associate director. Figure 2.1 shows the most recent organization chart of TTI.

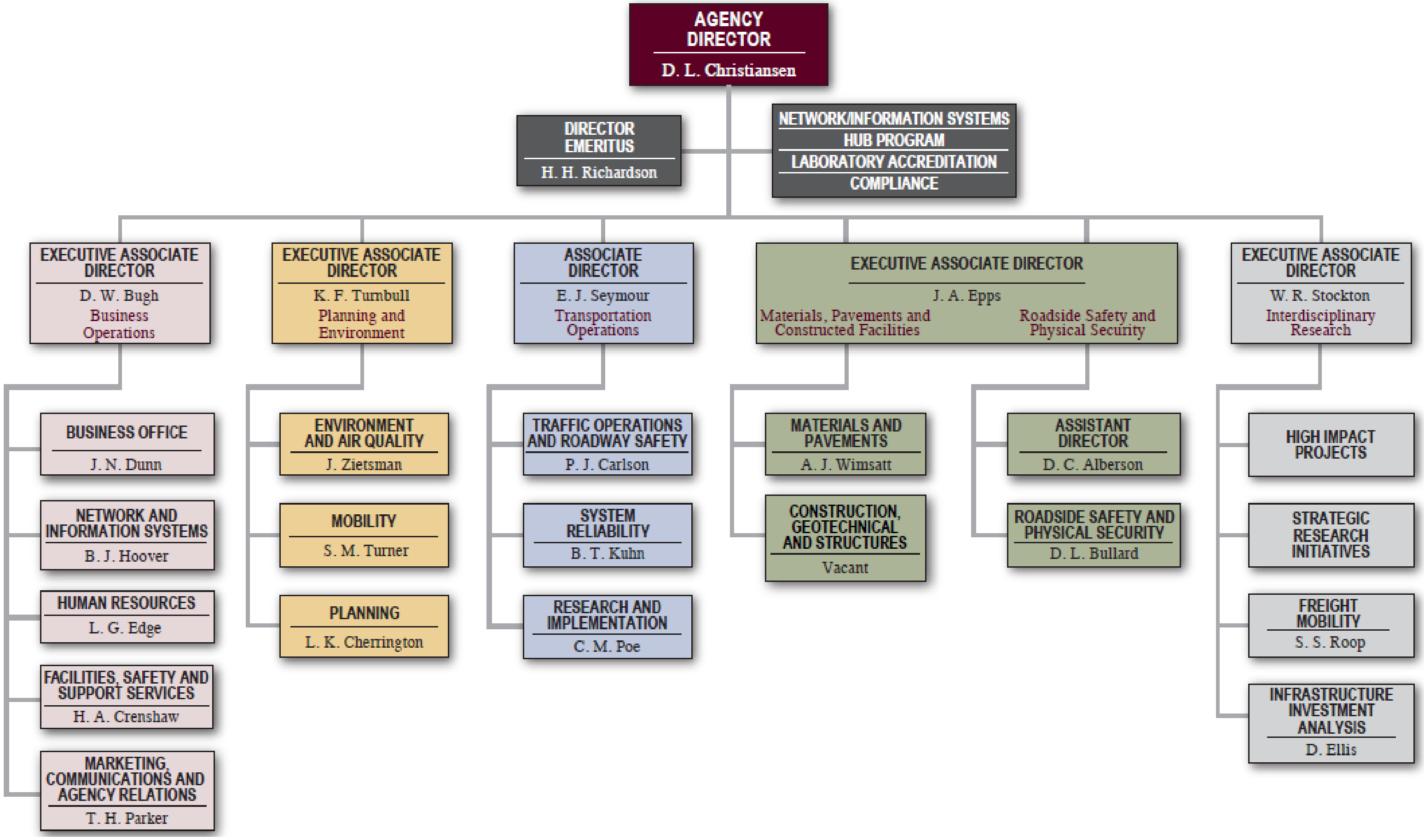
Materials and Pavements Division

My current workplace, the M&P Division of TTI, is located on the Texas A&M main campus. Some of its laboratories and facilities are located on Texas A&M's Riverside Campus. Dr. Andrew Wimsatt, P.E., my internship supervisor, is also the head of the M&P Division. Figure 2.2 shows the most recent organization chart of the M&P Division. The typical budget of this division is approximately $10 million. Typically, the M&P Division employs the following personnel:

- 30 full-time researchers,
- 12 part-time researchers (also faculty of the Texas A&M Civil Engineering Department),
- 5 full-time research technicians,
- 4 part-time research technicians,
- 2 administrative assistants, and
- 20 graduate research assistants (graduate students with part-time employment).

The M&P Division maintains the following laboratories and facilities to support its research and engineering business:

- Asphalt Binder and Chemistry Laboratory,
- Asphalt Mixture Testing Laboratory,
- Concrete Laboratory,
- Pavement Nondestructive Testing Facility,
- Pavement Profiler Evaluation Facility,
- Soils and Aggregates Laboratory,
- Falling Weight Deflectometer Calibration Facility, and
- Advanced Characterization of Infrastructure Materials (jointly with the Texas A&M Civil Engineering Department).



(Chart courtesy of TTI)

FIGURE 2.1 TTI organization chart.

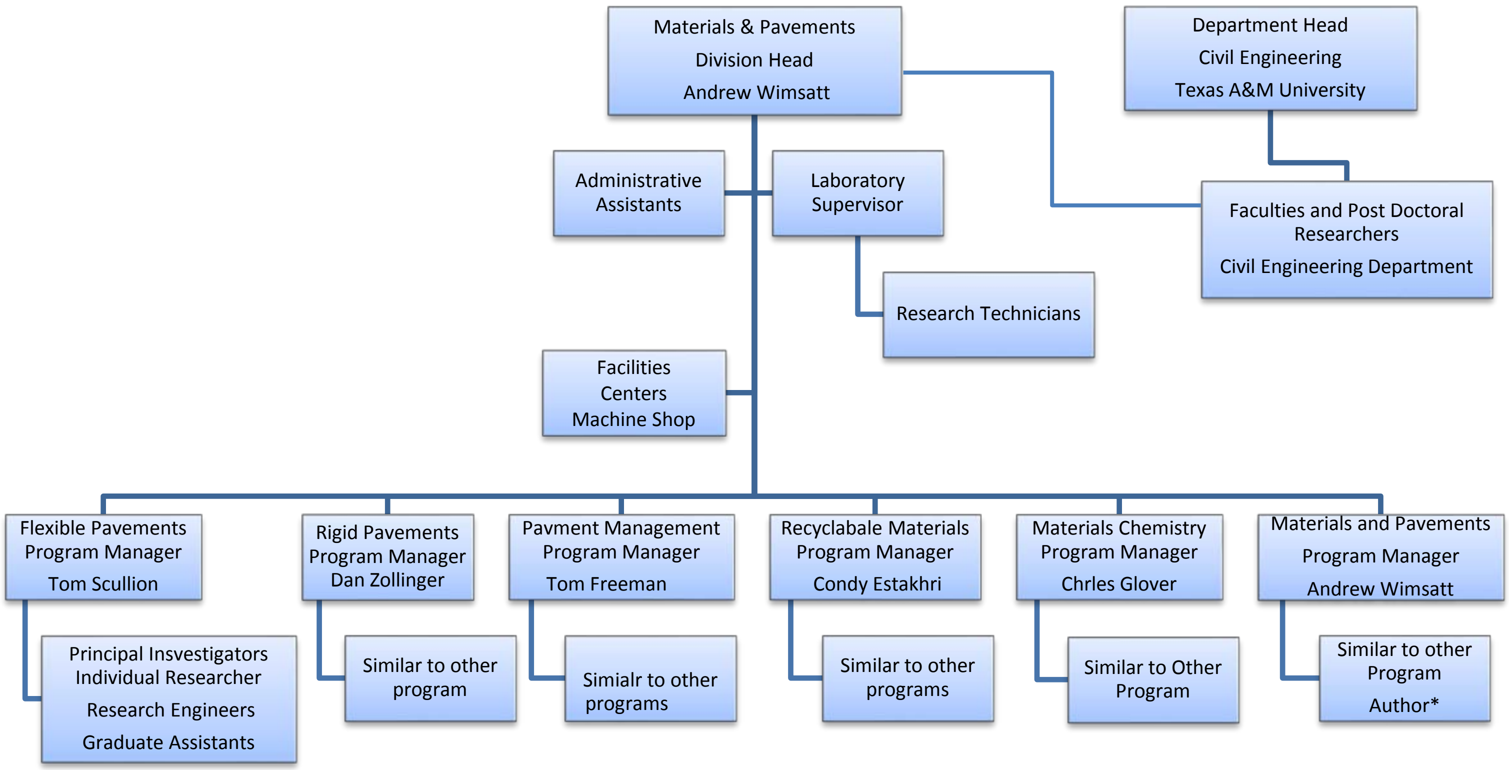


FIGURE 2.2 M&P Division organization chart.

Like other division heads, the head of the M&P Division is responsible for the programs within that division. The M&P Division has several programs headed by a program manager. The programs under the M&P Division include:

- Flexible Pavements,
- Rigid Pavements,
- Materials Chemistry,
- Pavement Management,
- Recyclable Materials,
- Construction, and
- Geotechnical.

Typical duties of the division head include acquiring information from the program managers and recommending salaries and wages, employment or dismissal, promotion, managing annual leave, personnel assignment to programs, purchases, office space, and inventory.

The program manager in turn is responsible for planning and staffing the program, preparing proposals, and communicating with other institute programs. The program manager assigns personnel to projects and, working with other program managers, recommends the assignment of personnel and personnel time to projects in his or her program.

The third level of management is the principal investigator (PI), who is totally responsible for technical and fiscal management of a project and for appropriate management of personnel assigned to that project. The hierarchy between program managers and PIs is not always straightforward. Programs managers or even division heads can work under the guidance of a PI for certain projects. One PI may simultaneously lead multiple projects. Most frequently, one individual researcher or employee works on multiple projects under different PIs. Project-specific teams are developed comprised of expert personnel from appropriate areas: from a single division, other TTI divisions, or even other departments of Texas A&M University.

Other Research Projects

In addition to the projects described in Chapters III and V of this ROS, I worked on three major research projects during the internship period. These research projects were sponsored by NCHRP and TxDOT. I was primarily responsible for managing the field activities of these projects. I performed field testing, sample collection, and test section monitoring. In order to perform these responsibilities, I needed to coordinate with construction contractors, material suppliers, other state department of transportation (DOT) officials, a traffic control contractor, and Federal Highway Administration (FHWA) mobile asphalt laboratory personnel. I led the TTI crew composed of researchers, graduate students, and technicians for sampling, testing, construction monitoring, and other data collection. In the field, I was responsible for ensuring the safety of the TTI crew and making sure that they followed appropriate safety protocols established by TTI. A significant amount of my time was devoted to coordinating and maintaining communication to carry out these jobs.

The following paragraphs give short descriptions of these studies and the nontechnical experience gathered from them.

NCHRP 9-49

NCHRP sponsored a study titled Performance of WMA Technologies: Stage I—Moisture Susceptibility, executed from 2010 to 2013. Dr. Amy Epps Martin, a professor of the Civil Engineering Department at Texas A&M University and research engineer at TTI, served as the PI of this study. The budget for this study was $450,000. The objectives of this study were (1) to evaluate whether warm-mix asphalt (WMA) technologies adversely affect the moisture susceptibility of asphalt pavements and (2) to develop guidelines for identifying and limiting moisture susceptibility in pavements with WMA. In order to fulfill the objectives, among other tasks, the research team performed testing with a number of field test sections. I was responsible for managing these four test sections located in Iowa, Montana, New Mexico, and Texas. Samples were collected during construction and also periodically after construction. Sample collection long after construction also required coordination with DOT personnel, a traffic control contractor, and a shipping company. I conducted some on-site testing and specimen preparation. At the end of the study, along with my teammates I co-authored a comprehensive research report, *NCHRP Report 763: Evaluation of the Moisture Susceptibility of WMA Technologies.*

NCHRP 9-52

NCHRP sponsored a study titled Short-Term Laboratory Conditioning of Asphalt Mixtures, which is ongoing. Dr. David Newcomb, a senior research engineer at TTI, is the PI of this study. The budget for this study is $800,000. This TTI-led study has two other partner organizations: the University of California at Davis and the National

Center for Asphalt Technology. The objectives of this study are to develop procedures and associated criteria for short-term laboratory conditioning of asphalt mixtures for mix design and performance testing to simulate the effects of (1) plant mixing and processing to the point of loading in the transport truck and (2) the initial period of field performance. I led the field part of this project, which included identifying and monitoring six test sections in Iowa, New Mexico, Texas, South Dakota, and Wyoming. I also coordinated with partner organizations for the additional three test sections constructed in Florida, Indiana, and Connecticut.

TxDOT Project 0-6992

This study, titled Develop Practical Field Guidelines for the Compaction of HMA or WMA, was sponsored by TxDOT. Mr. Tom Scullion, a senior research engineer at TTI, was the research supervisor for this project. This two-year study was carried out jointly with the University Texas at San Antonio. The objectives of this study were to conduct a comprehensive evaluation of compaction of asphalt pavements and to develop a computer program for monitoring field compaction of asphalt mixtures in real time. I was responsible for managing field and laboratory testing. I led the activities involving testing at five test sections in different parts of Texas. This project involved instrumentations of construction equipment (a paving roller and paver) during the paving at all five test sections. I had to contact and convince the contractors to get their permission and make sure that the research activities in the field did not negatively affect the contractors' activities during paving operation. I led a field crew consisting of three researchers and two technicians.

TTI as DEng Internship Location

Although TTI is primarily a research institute, there are many opportunities to learn and practice managerial or nontechnical skills while serving as a research engineer. The organizational structure of TTI and the M&P Division, and the management techniques employed by some PIs, can make TTI an ideal place for a DEng internship. In a number of instances, situations at TTI met the internship criteria recommended by the DEng program.

CHAPTER III

TRAINING IN KOSOVO

Background

Kosovo emerged as the world's newest independent state in early 2008 after more than a decade of war and political unrest. But the country's transportation infrastructures were severely deteriorated and in need of urgent reconstruction. In September 2008, USAID awarded the Kosovo Private Enterprise Program (KPEP) to Booz Allen Hamilton (BAH), an international strategic management and technology consulting firm headquartered in McLean, Virginia. KPEP aimed to stimulate private-sector competitiveness in Kosovo. KPEP consisted of four components: private-sector support in targeted sectors, demand-driven business support services, an improved business-enabling environment, and workforce development. KPEP also addressed cross-cutting areas including gender, youth, and minority development in Kosovo.

Both residential and commercial sectors made significant contributions to Kosovo's gross domestic product. During the inception of this project in 2010, the project team anticipated that the road construction funding from the government of Kosovo and international donors would exceed 80 million euros annually for the next several years. Both public- and private-sector construction and rehabilitation were also driving growth in the construction materials sector. Key growth areas included the road construction and building materials manufacturing subsectors.

KPEP focused on these two subsectors, road construction and building materials, with the objective of building capacity in the subsectors and increasing jobs, sales, and investment. TTI's involvement was related to the road construction subsector.

Road Construction Subsector

KPEP's objective for the road construction subsector was to improve road design capabilities and procurement processes, and build the capacity of construction contractors and the construction workforce. In 2010, KPEP, in collaboration with TTI, conducted a needs assessment task for road construction companies in Kosovo. Findings of this task suggested the following:

- There is a lack of officially adopted and/or widely used design standards and construction specifications for road infrastructure in Kosovo. The task team recommended that efforts be made to increase awareness and promote the need for formal and uniform adoption of road design standards and construction activities.
- Technical assistance is needed to address parts of the project management gap. Specific areas of concern under this need are cost estimation and bid preparation, works planning and scheduling, cost and resource management, construction site safety, and quality control and quality assurance (QC/QA).
- Use of standardized contract forms and contract management procedures and practices is very limited and needs to be improved.

The need for training came from this assessment TTI conducted in 2010. The needs assessment identified the lack of official or widely used design standards and construction specifications for road infrastructure in Kosovo. Transportation engineers in Kosovo had limited road design and supervisory experience, and this presented a critical shortcoming. One of KPEP's objectives in the road construction subsector was to improve the road design capabilities of local road design and construction companies. To fulfill that objective, KPEP signed a memorandum with TTI to provide a detailed certified program/specialization for road design in cooperation with the University of Pristina. The specialization program targeted mainly graduate civil engineers from private road construction businesses but also included some candidates from university and public institutions (government agencies). Initial estimates of candidate trainees were as follows:

- 25 road design and road construction graduate engineers,
- 5 technical government staff (Ministry of Transportation), and
- 10 post-graduate students from the Department of Civil Engineering of the University of Pristina.

It was decided that the specialization course would be delivered at the facilities of the University of Pristina. The specialization course is composed of three modules with five subject areas, as shown in Table 3.1.

TABLE 3.1 Training Modules for Kosovo

Module	**Subject**
I	Traffic Engineering
	Highway Geometric Design
II	General Principles of Road Structure Design
III	Road Pavement Design
	Road Construction QC/QA and Supervision

Scope of Work

The scope of work under the contract between KPEP and TTI included providing lectures on five specific areas of transportation engineering and final examinations at the end of each of these five areas:

- Traffic engineering,
- Highway geometric design,
- General principles of road structure design,
- Road pavement design, and
- Road construction QC/QA and supervision.

Deliverables, mentioned in the scope of work, included the curriculum for each subject:

- A lecture syllabus,
- Course materials,
- An examination,
- International certification for the lectures and examination,

- A comprehensive end-of-seminar report (using a template provided by KPEP),
- Weekly briefings with KPEP, and
- A final briefing with USAID.

The road design training was developed to provide participants with a solid understanding of road design fundamentals, use of uniform design standards and guidelines, and the importance of overall project planning.

TTI Team

Dr. Rafael Manuel Aldrete, P.E., was the leader of the TTI team. He is a senior research scientist and manager of TTI's Research and Implementation Office located in San Antonio and El Paso, Texas. Besides me, other team members included Roma Stevens, P.E., David Galicia, Tom Freeman, P.E., and Robert Benz, P.E. Initially, Ms. Roma Stevens and I assisted the team leader to form the team by finding and recruiting other members for this project. I was assigned to develop and deliver training Module III, and Mr. Tom Freeman assisted me in this task. Ms. Roma Stevens and Mr. Robert Benz were in charge of Module I and Module II, respectively. Dr. David Galicia assisted in both Module I and Module II. During the development of the course, I consulted with the senior pavement engineers at TTI. The team also sought permission from different organizations to use their copyrighted materials.

Development of Training Materials

Initially, I knew only the major topics of Module III, mentioned in Table 3.1, on which to develop the two-week training course. At the time, I had more than 12 years of experience in the field, but it was very challenging to design and develop a course without a clear idea of the target audience, their needs, and their local standards and practices. With the help of the team leader and other instructors, I contacted BAH employees, the principal contractor of the project in Kosovo, and the faculty at the University of Pristina to gather more information about the local conditions, standards, needs, backgrounds, and level of participants' knowledge.

Selecting the standard of pavement design posed a dilemma. My first idea was to teach local design standards, only to discover that there were no standards. Local pavement designers mainly used charts and tables to select pavement thickness based on traffic count and did not use any analysis. Standards commonly used in other European countries required English translation and a significant amount of time to become familiar with them. I also considered the recently developed *Mechanistic Empirical Pavement Design Guide* (MEPDG) developed by the American Association of State Highway and Transportation Officials (AASHTO). Considering the current state of the practice in Kosovo, and the practical issues related to the implementation of MEPDG standards in an underdeveloped country like Kosovo, after consulting with team members I decided to teach AASHTO's pavement design standard developed in 1993. The 1993 AASHTO *Guide for Design of Pavement Structures* is primarily based on empirical observations from the American Association of State Highway Officials (AASHO) Road Test that began in the 1950s. The 1993 AASHTO guide requires fewer inputs and is relatively easy to implement.

Before this project, I had no experience in developing training courses longer than two days. I consulted with other senior research engineers at the M&P Division about the course design, its contents, and their appropriateness. The personnel I consulted with—Mr. Tom Scullion, Dr. Andrew Wimsatt, and Dr. Jon Epps—provided valuable suggestions and guidance during the development of this course.

I also contacted several organizations for permission to include their copyrighted materials in the course contents: the Washington Department of Transportation, the National Center for Asphalt Technology, the National Asphalt Pavement Association, and two publishing companies. As expected, obtaining permission from the non-profit agencies was relatively easy, but obtaining permission from the for-profit companies required significant effort.

Tables 3.2 and 3.3 provide the outline and course contents for the Road Pavement Design and the Road Construction QC/QA and Supervision training subject areas, respectively.

The learning objectives of Module IIIa (or first week of Module III) - Road Pavement Design were to:

- Characterize soils, unbound aggregate materials, and asphalt layers in the flexible pavement structure to account for their moisture, stress, and time-sensitive behavior under traffic and environmentally induced loads;
- Be familiar with pavement performance concepts including distresses, serviceability, and roughness;
- Understand how to evaluate the in situ structure of a pavement and how to design appropriate rehabilitation using the AASHTO 1993 guide; and

- Apply the AASHTO 1993 guide for new pavement construction and low-volume pavement.

TABLE 3.2 Outline and Course Contents for Road Pavement Design

Topic	**General Description**	**Time Required (Hours)**
Introduction and Overview of Pavement Design	Course Introduction, Types of Pavement Systems, History of Pavement Design, Different Design Methods	2
Materials Characterization	Subgrades, Chemically Stabilized Layers, Aggregate Layers, Asphalt Layers	6
Traffic and Environmental Effects	Traffic Loading and Volume, Design Procedures, Equivalent Single Wheel Load, Equivalent Axle Load Factor, Environmental Effects on Pavement Design	3
Pavement Performance	Distress, Serviceability, Reliability, Roughness, Surface Friction, Nondestructive Testing, Determination of In Situ Properties	5
Pavement Structural Design	Flexible Pavement Design Procedure Using AASHTO 1993 Standard, Design Inputs, Flexible Pavement Shoulder Design, Practice Problem	7
Pavement Rehabilitation	Rehabilitation Methods Other than Overlay, Rehabilitation Methods with Overlay, Pre-overlay Repair, Overlay Thickness Design, Practice Problem	4
Pavement Drainage	General Considerations, Drainage Materials, Drainage Procedures	1
Low-Volume Pavement	Design Considerations for Flexible Pavement and Aggregate-Surfaced Roads, Design Chart Procedure, Design Catalog	2

TABLE 3.3 Outline and Course Contents for Road Construction QC/QA and Supervision

Topic	**General Description**	**Time Required (Hours)**
Introduction	Overview of Different Stages of Highway Construction, Concept of Construction Supervision, Concept of Quality Assurance and Quality Control	2
Subgrade and Base Construction	Equipment, Transportation and Construction of Earthwork, Embankment, Stabilization, Flexible Base	5
Hot-Mix Asphalt (HMA) Construction	HMA Facilities/Plants and Equipment, Transportation and Laydown Operations, HMA Compaction	6
Miscellaneous Construction Including Concrete Structures	Minor Drainage Structures, Concrete Curb and Gutter, Sidewalks, Etc.	3
Construction Inspection	Item Checks during the Construction Inspection and Workmanship for Various Stages/Items of Highway Construction	3
Quality Assurance and Quality Control	Acceptance Program, Independent Assurance Program, Conflict of Interest and Dispute Resolution, Sampling and Testing Personnel Certification Program, Laboratory Qualification Program, Acceptable Tolerance Limits, Setting Up Contractor's Quality Control Plan	8
Sampling and Testing	Schedule or Frequency for Sampling and Testing of Various Items in Highway Construction such as Embankment, Sub-base, Flexible Base, HMA, Nonstructural Concrete, Structural Concrete, Etc.	2
Partnership between Stakeholders	Public Relations, Relationship between Agency and Contractor, Relationships among Agency Personnel	1

The learning objectives of Module IIIb (or second week Module III) —Road Construction QC/QA and Supervision were to:

- Identify components of workmanship related to different stages of highway construction,
- Describe the role of each construction team member (owner, contractor, inspector, and engineer) in achieving quality workmanship,
- Apply QC/QA concepts,
- Know the laboratory and personnel certification program, and
- Describe the importance of partnership between stakeholders.

Certification of Training Course

As per the contract with KPEP, TTI contacted the Institute of Transportation Engineers (ITE) to obtain certification for the training course. The objective was to make sure that the course met the international standard. At the onset of course development, the TTI team teleconferenced with ITE staff to discuss their requirements and deadlines for course certification. Accordingly, the TTI team sent the following items for ITE's evaluation:

- The instructor's biography including any past instructional experience,
- A course description and learning objectives,
- A detailed agenda for each course day to determine the appropriate number of course credits,
- Course materials for nontechnical feedback from ITE, and
- Quizzes/assessment of the course.

The ITE review of draft course materials focused on examining the opportunities for interaction with instructors and participants, readability/usability of course materials, and flow of contents. Their nontechnical feedback was beneficial to the course. ITE reviewed training materials, including learning objectives and exams, for visual quality, ease of comprehension, and appropriateness. Based on the recommendations from ITE personnel, the team members made appropriate changes during course development to comply with ITE standards. After revisions, the course met ITE's certification criteria for contact hours and presentation materials. Participants successfully completing a module (who met the attendance standard and passed the exam at the end of the module) received a completion certificate for that module from ITE. This certification by ITE helped standardize the training and further stresses the importance and usefulness of following standard design and construction procedures for all projects. The completion criteria for the training were having a 90 percent attendance and obtaining a passing score (60 percent) on the exam. An electronic copy of the training materials was provided to each of the training participants before the training began.

Delivering the Course

Mr. Tom Freeman and I traveled to Pristina, the capital city of Kosovo, to deliver the Module III training. As planned earlier, Mr. Freeman remained there only the first week of this two-week course. Since it was the third module, we received some tips from fellow instructors who had already delivered their respective modules. Tips regarding the facilities, participants, and local conditions helped us to be better prepared.

A faculty member of the University of Pristina Civil Engineering Department acted as the local coordinator and was extremely helpful.

The course was delivered in a classroom seating, as shown in Figure 3.1. The instructors, Mr. Tom Freeman and I, mainly used PowerPoint presentations to deliver the course. We occasionally used other visual aids like flip charts, blackboards, videos, and an overhead projector. We took efforts to make the class interactive as much as possible. Occasionally, participants were invited to the podium in order to keep them engaged and stimulated. At the beginning of the course, we reviewed the learning objectives with the participants and asked them their expectations. Based on popular demand, we made some modifications to the course contents, mainly the Road Construction QC/QA and Supervision subject area. Before making the actual changes, we consulted with the team leader and the local BAH representative, and followed the general guidelines from ITE. Although the subjects were not initially included in the course contents, I included and discussed new topics due to demand from the participants—HMA design, characteristics of special mixtures like stone matrix asphalt, open-graded friction course, and characterization of pavement skid resistance. Fortunately, I had some related materials and PowerPoint presentations on my laptop that helped me prepare some new materials in the evenings.

FIGURE 3.1   Participants during pavement design course.

During the second week of Module III, I was able to arrange a laboratory tour at the civil engineering materials characterization lab at the University of Pristina to demonstrate the use of some of their equipment and testing procedures. Despite the demand from the students, I could not provide hands-on experience in testing due to lack of time. On another occasion, with the help of a BAH engineer, I arranged a field trip to a highway construction site. The participants liked this field trip because they had an opportunity to use their recent lessons from the course.

As previously mentioned, during the first week of the training, I was assisted by Mr. Tom Freeman. I delivered the second week of the training course on QC/QA of road construction alone. Lecturing alone all week is somewhat difficult, so to overcome this issue, I made some changes in instruction style. For example, I asked a few experienced participants to share their experiences at certain intervals, and I asked the participants to complete some small assignments. This gave me some breaks from lecturing as the lone instructor.

During training days, an attendance sheet was maintained according to ITE's requirement. At the end of the course, participants were asked to fill out the course evaluation forms designed by ITE. Later, all course exam answer sheets, attendance records, and evaluation forms were submitted to ITE for verification and certification.

Participants

Thirty-three participants from private road construction and design firms and the Kosovo Ministry of Transport, as well as graduate students and faculty from the University of Pristina, attended all three modules of this five-week intensive training course. The participants came with a wide variety of knowledge, experience, and backgrounds. Their diversity created unique opportunities and challenges for the instructors. A few participants were fluent in English, but the rest had only a working knowledge of English. Although most of the participants' listening and reading skills in English were acceptable, their English-speaking skills were moderate to poor. During the course, the instructors asked for help from the experienced participants with better English-speaking skills to translate into the local Albanian language. Some students had overseas work experience and were very knowledgeable about different design and construction standards and practices.

Evaluation of Training Course

Brochures about the training course that were circulated before the course generated huge interest in the professionals working in design and construction firms in

Kosovo, and the KPEP office received more than 100 requests to participate in the training. However, class size was limited to 30 participants to maintain the effectiveness of training and provide maximum possible benefits to the participants. Ultimately, the number of participants grew to 33.

Instructors had fruitful discussions with participants during, after, and in between lectures that suggested that the training course was very useful to the participants and stressed the need for quality design and construction of roads. The training course not only provided participants with understanding of quality design and construction fundamentals, but also made participants familiar with available resources for future reference.

In addition to the topics specified in the initial training outline, instructors covered additional topics such as transportation project planning, use of intelligent transportation systems (ITS), design of HMA, design of reinforced concrete pavements, and textured pavement materials for skid resistance improvement as requested by participants during the training. Field trips offered during Modules IIb and IIIb were described by students as highly productive since they had the opportunity to see in the field several concepts previously explained during classes. Moreover, students evaluated the existing conditions of some of the main highways connecting the city of Pristina with other important cities in Kosovo, and proposed some possible alternatives to improve current road structures.

Feedback and evaluation forms from the participants indicated training objectives were met for over 90 percent of the participants. Exam scores also suggested good delivery of the material by instructors and equally good understanding by the participants.

Based on the discussions during training delivery, instructors found the training course to be very useful for the participants. Even though there were only two field trips and one laboratory visit for two different modules, the participants expressed a great deal of interest by asking about concepts and alternative designs learned in the classroom, and applied their own criteria to find an optimal solution to some of the existing problems with their transportation infrastructures. Instructors recommended inclusion of field trips in future training to have a more solid understanding of the theory.

The project team feels this training was a success in achieving its goals and recommends a repeat of the training to satisfy the huge interest, with some additional topics such as transportation planning and ITS. TTI and the University of Pristina signed a memorandum of agreement setting up a transportation graduate degree program there. Dr. Naser Kabashi, dean of the faculty of Civil Engineering and Architecture at the University of Pristina, stated that the training course brought together participants with different levels of expertise who exchanged individual knowledge and best practices on common concerns.

While I believe that a five-week training course is not long enough to cover all aspects of transportation engineering well enough, the students had the opportunity to learn both basic and advanced topics of roadway geometric design, traffic engineering, roadside safety and roadway drainage, pavement design, and highway construction. The instructors taught the theoretical models, how these are implemented in the United

States, and how the participants can adapt and adopt these technologies for the conditions in Kosovo. The instructors provided easily accessible references and sources of information that students can explore further to enrich their knowledge.

The engineers and technicians needed formal training to help them become competent to support their ongoing rapid development projects in Kosovo. The training program conducted by TTI has paved the way for delivering another cycle of training in Kosovo and helping them to develop their curriculum for transportation engineering graduate study.

Lessons Learned

This project provided a unique opportunity for me to enhance my technical, teaching, managerial, and communication knowledge and skills.

The training project in Kosovo enabled me to apply my knowledge and experience in pavement design and highway construction. I was not an expert in all the topics; I had to study reference materials for a significant amount of time to be able to develop the course materials. Preparing for the course also enhanced my knowledge in the field along with improving my expertise in developing and delivering training courses. The effort made me become familiar with the design and construction standards practiced in a developing country. Through this training program, I was able to apply my knowledge of cross-cultural diversity that I learned from management courses taken at Texas A&M University. I had prior experience working in both developed and developing countries, and I was able to practice my skill of working and interacting with people from a different country, language, and background. Developing and delivering these courses under a relatively tight schedule and maintaining the standards of different organizations provided me with new managerial and communication skills.

I also participated in the NHI-offered instructor development course described in Chapter IV. There I learned extremely valuable lessons of developing and delivering training courses effectively. But I attended the course after the completion of Kosovo training project. I recognize that I could have done several things differently in Kosovo had I participated in the instructor development course prior to the Kosovo project. The most notable difference I could have made was applying different techniques to make the training more interactive. By making the training more interactive, the instructor can draw more interest and attention from the participants and thereby convey the message more effectively. Another idea for better communication is dividing the participants into smaller groups where each group has at least one person with proficiency in English. That person could translate for other participants in the native Albanian language. During the second week of Module III, I noticed fatigue among the participants. It was their fifth straight week in this program. I would recommend scheduling some breaks so that the participants could digest the recently learned knowledge and prepare for the next modules. A training course of this nature should not be longer than two weeks at a time.

The training course certification process and the handling of copyrighted materials are new areas of knowledge that I gained. Considering all the new knowledge and skills learned during this project, I believe that I met the learning objectives set for the DEng program.

CHAPTER IV

PROFESSIONAL DEVELOPMENT

Continuing professional development (CPD) is essential in an organization because it ensures the employees continue to be competent in their professions. CPD is an ongoing process, continues throughout a professional's career, and helps him or her continue to make a meaningful contribution to his or her team. CPD helps employees to advance in their career and move into new positions where they can manage, lead, shape, coach, and mentor others. During the internship period, I participated in several professional development training courses offered by TTI and outside organizations. The major training courses I participated in were:

- The Delta-T leadership development program offered at TTI,
- The Instructor Development Course offered by NHI, and
- Time Management and Organizational Skills course offered by the Texas A&M Engineering Extension Service (TEES).

This chapter also includes a description of my effort to coordinate a lecture series in order to enhance communications in the M&P Division.

Delta-T Leadership Development Program

TTI offered the Developing Leaders for Today and Tomorrow, or Delta-T, training program to its employees to groom them for leadership. This program existed from 2008 to 2012. TTI employees were nominated annually as a class focused on learning skills and strategies to improve their overall leadership capabilities. Each class also developed a project related to TTI, its processes, or employee development. The project reports are posted on the TTI intranet as resources. After the 2012 class, Delta-T was replaced by a separate and more elaborate leadership development program called the Leadership Enhancement and Development (LEAD) Program.

Effective leadership is critical to the long-term success of an organization. It is important to remember that leadership is not limited to any particular designation such as "program manager" or "leadership team member," nor is the characterization of leadership confined to any one particular definition. Leadership can mean, for example, promoting the vision of an organization, establishing new directions, or moving the organization and its people forward to meet the challenges of the future. Leadership is not simply supervising people. The most successful organizations have a plan for identifying their future leaders and cultivating those skills. TTI describes the benefits for the participants of this training program as:

- Providing various opportunities to learn, develop, and sharpen leadership skills;
- Enhancing leadership knowledge, experiences, and skills applicable in personal, professional, and volunteer environments;
- Creating a network of peers and resources for personal and professional growth;
- Strengthening the ability to manage and lead the organization; and
- Providing opportunities to interface with the Leadership Team.

The organization, in this case TTI, can benefit from this program in the following ways:

- Identifying and preparing individuals for leadership positions within TTI,

- Demonstrating TTI's investment in leadership development,
- Developing visionary leaders with strategic focus, and
- Increasing opportunities for members to contribute to the organization.

For each Delta-T class, 12 participants were selected among the employees nominated by other employees and supported by their supervisor. At the time, the requirements were as follows: The prospective participant must have a minimum of three years of full-time work experience at TTI. The participant must be nominated by another TTI employee, and his or her participation in the Delta-T program must be supported by the employee's supervisor.

A selection committee reviewed all of the nominations and finalized a list of 12 participants. The final group of participants was selected based on their nomination essay and demonstrated interest in TTI operations (committees, etc.). Also, the makeup of the Delta-T program reflected the overall structure of TTI. The selection committee made an effort to form the group with diversity in job classification, geographic location, and program representation.

Delta-T Training Activities

Participants in the Delta-T program attended four half-day workshops at the TTI headquarters located in College Station. The four half-day workshops were spread out over six months. Workshop activities included leadership introduction, leadership fundamentals, participant self-assessment, book discussions, presentations by guest speakers, small-group activities, leadership assessments, and other activities. Participants were also required to complete a group project and give a final presentation to the TTI Leadership Team. Dr. Gary Thomas, a research engineer and director of TTI's Center for Professional Development, was the lead instructor for this course. Dr. Thomas was supported by Dr. Dean Alberson, assistant agency director and manager of the TTI Crashworthy Structures Program. In addition to these four workshops, the group met at other times to work on the project.

During the class, the participants read and discussed the following books on leadership:

- *The People Code* by Dr. Taylor Hartman;
- *Good to Great* by Jim Collins;
- *The Leadership Moments—Nine True Stories of Triumph and Disaster and Their Lessons for Us All* by Michael Ussem; and
- *Now, Discover Your Strengths* by Marcus Buckingham and Donald O. Clifton.

A number of distinguished speakers made presentations on leadership in an informal setting. Each was highly successful in his or her role as a leader at TTI and other organizations. During the presentations, they shared their leadership experience with the participants and answered questions. The speakers came from different backgrounds, and their leadership styles were diversified and sometimes contrasting as well. The speakers were:

- Dr. Dennis Christiansen, TTI executive director;
- Dr. Joseph Cerami, director of the Public Service Leadership Program at the Bush School of Government and Public Service;

- Dr. Bill Stockton, TTI executive associate director and head of the TTI Interdisciplinary Research Group;
- Don Bugh, executive associate director and head of TTI Business Operations;
- Dr. Herb Richardson, TTI director emeritus; and
- Gregg Mitchell, president of Trinity Industries.

Delta-T Team Report

The Delta-T team was given the option to choose one topic among a few suggested topics as their team project. After some debate, the team unanimously chose to work on a topic dealing with improvement of TTI's research deliverables. After half a dozen team meetings and some research, the team compiled a report titled *Evolving Our Research Deliverables*. The team presented the findings of this report to the TTI Leadership Team, which is made up of upper management and division heads. This section gives a short description of the report's problem statement, research methodology, findings, and recommendations. The complete report appears as an appendix to this ROS.

The traditional outcome of most research projects is disseminated in a written report that documents the research methodology and results. This deliverable format does not always maximize available technologies, nor does it promote broad-range information sharing to an audience that may include future research sponsors. The team believes that researchers should maximize the value of a project deliverable including usability, timeliness, and use of highly interactive features and information-sharing techniques. The team believes that the proper enhancement of project deliverables will have significant benefits, including the promotion of past and current research and potential growth in the TTI research program.

This project examined the current state of project deliverables as well as potential enhancements that could be made, keeping in mind that any changes should integrate smoothly with current research activities while also expanding appeal to additional types of potential users outside the traditional research community. This was accomplished through the following tasks:

- Review literature on successful project deliverables,
- Review current deliverable usage statistics,
- Conduct interviews to garner the perspective of affected parties both inside TTI and sponsors,
- Develop a deliverables matrix to define how and when different enhanced deliverables should be considered, and
- Create examples of enhanced deliverables.

Based on these tasks, the team looked at ways current technologies could be used to enhance project deliverables. This information is documented in the deliverables matrix of possible enhanced deliverable implementation ideas. Additionally, the team recommends that TTI form an implementation team to further develop the concept of enhanced project deliverables. The implementation team should include a cross section of expertise within TTI and oversee the following tasks:

- Develop a pilot program to determine the effectiveness and cost/benefit of enhanced project deliverables,

- Formalize the proposed deliverables matrix to guide researchers in the selection of specific deliverable enhancements,
- Develop a framework for the implementation of specific deliverable enhancements to guide researchers to the resources necessary for the specific product, and
- Develop a metric to evaluate the performance of the enhanced project deliverables.

Instructor Development Course

Transportation workforce development is part of TTI's mission statement. Without implementation, the valuable research performed by TTI researchers for the transportation industry could sit on a shelf and collect dust. One way to get the word out is to arrange seminars and workshops like the Transportation Short Course for TxDOT. Each year, TTI researchers provide training on a wide range of transportation topics, sometimes as part of dissemination of their research findings and sometimes to train people about existing technology in order to improve the transportation infrastructure. Recent topics that TTI instructors have taught include design and operation of intersections for safety, freeway management and operations, traffic signal design and operations, work zone management and design, new approaches to highway safety analysis, pavement design, state and metropolitan transportation planning, and HMA construction quality improvement using ground-penetrating radar and the PAVE-IR bar.

Training courses are occasionally a two-way learning process. Dr. Gary Thomas, said, "The people we teach aren't just students; they have life experiences that they bring to the classroom, and we always learn something from them. We incorporate that valuable information into the next workshops we teach" (TTI 2010).

TTI's workforce development efforts encompass a wide range of ages and transportation fields. Personnel from TTI educate the current workforce by offering training, seminars, and workshops. They educate the future workforce by sponsoring students and their research projects. They educate the very youngest future transportation professionals by showing students the many opportunities that await them as engineers and planners. Through their efforts of educating others, the researchers at TTI learn the community's needs, what TTI can provide, and how they can work together to get it done.

TTI's reach for workforce development extends internationally as well. In recent years, TTI researchers traveled to Kosovo, the United Arab Emirates, Thailand, and Mexico to share their expertise and also learn from their students' different worldviews and perspectives.

NHI Training Course

NHI offers the Instructor Development Course each year at different locations in the United States. The objective of this course is to provide new and experienced instructors with the knowledge and skills to deliver more effective training. NHI defines training as a "demonstration of acquired skills and knowledge of adult learning principles which necessitates that learning outcomes be developed and their attainment be measured" (National Highway Institute 2014). This course was intended and designed for instructors who will be delivering interactive training to adult learners, especially professionals.

A skilled trainer, therefore, emphasizes the use of experiential learning techniques, such as problem-solving analysis, discussion, question and answer sessions, group activities, demonstrations, and roleplaying (National Highway Institute 2000). In essence, these learning activities tap into the knowledge and skills that an adult learner brings to the classroom, and have the goal of meeting both the learning outcomes and the participants' expectations.

The expected outcomes of this 3.5-day training class were that participants would be able to (National Highway Institute 2014):

- Explain the five steps in the instructional system design;
- Perform analysis, design, development, implementation, and evaluation;
- Write a behavioral learning outcome;
- Present, measure, and review a learning outcome;
- Demonstrate at least two forms of interactivity and positive interpersonal skills;
- List five training techniques (e.g., do not talk to the flip chart, do not stand in front of the projector, and do not stand in one place);
- Demonstrate how to reach the three styles of learning; and
- Deliver a 15-minute training session that demonstrates adult learning principles.

The training class covered the following major topics through different learning media:

- Introduce adult learning,

- Prepare for training,
- Conduct the training,
- Practice the training, and
- Conduct a post-training review.

I attended this training in Madison, Wisconsin. There were 10 participants from different engineering backgrounds with varying degrees of work experience, all of them somehow related to the transportation industry. A master trainer from NHI taught this course.

The best aspect of this training was that the instructor practiced what she was teaching. By creating a very interactive environment, the instructor made the class enjoyable for adult learners. During this training course, I clearly identified a few areas that I needed to improve to become an effective instructor. The 15-minute practice training, with recorded video for future evaluation and evaluation from peers and the master trainer, was extremely helpful. The course instructor pointed out my strengths and weaknesses after the practice session.

My next step will be to become an NHI-certified instructor. Doing so will allow me to teach NHI-offered courses where I already have subject matter expertise. Being an NHI-certified instructor requires successfully conducting at least a one-day training course in the presence of an NHI master trainer. I think that it would have been more effective if I had completed this training before the Kosovo project. I am confident that the knowledge and skills gained during this course will make me a more effective instructor.

Time Management and Organizational Skills Course

During the internship period, I participated in a time management and organizational skills course in addition to several other professional development training courses. This training was arranged by TEES and presented by the National Seminar Group, a division of the Rockhurst University Continuing Education Center, Inc. The objective of this training program was to provide the participants with an essential set of skills and tools that will make a significant and immediate impact on their daily productivity and efficiency. It was designed to teach the attendees how to manage deadlines so that ultimately the project stays on time and on budget. This one-day training workshop focused on discussing the latest project-management techniques and prioritization tools so that employees are able to identify and eliminate behaviors and habits that sabotage their progress (Rockhurst University Continuing Education Center, Inc. 2010). This training enabled me to learn and practice the following items:

- How to focus your efforts where you will make the most difference in your results and let go of nonessential tasks—activities that eat away your time and energy;
- How to handle multiple priorities;
- How to set deadlines in a way that wins agreement and gets commitment (yours and theirs);
- How to evaluate priorities each day to make sure the true top priorities get handled;
- How to identify and cut time-wasting activities;

- How to organize for efficiency and make good organization a habit;
- How to handle the pressure of juggling people, paper, and priorities;
- How to work with people and keep positive relationships with others by establishing balance, and how to tactfully manage people who interrupt; and
- How to keep quality high while productivity goes up, avoiding the pitfall of perfectionism.

The training was very useful. It presented different techniques to fight procrastination. The most important part of the training was not just learning techniques but practicing them on a regular basis and making them a habit.

Seminars at M&P Division

It has long been recognized and discussed among TTI employees and management that the state of internal communications at TTI is poor. Communications between researchers of different divisions or among researchers in the same division are not as great as they should be, especially for a world-class research organization like TTI. There are cases where outside people have pointed out that someone at TTI is doing the same/similar research that another researcher at TTI is doing, causing duplication, missed opportunities, and inefficiency.

The TTI M&P Division has recently drafted a strategic activities plan, and one of the activities is to improve internal communications. Several activities have been proposed in order to achieve this goal. One of them is to organize a seminar series. Technical experts from outside TTI or the Civil Engineering Department would be invited to deliver presentations on their current activities. After discussing this issue with Dr. Jon Epps, executive associate director and head of TTI’s Materials, Pavements, and Constructed Facilities, I volunteered to arrange a seminar-type lecture series. This lecture series was arranged in conjunction with the seminar class taught by Dr. Jon Epps at the Civil Engineering Department of Texas A&M University. One of the objectives of this seminar series was to enhance the internal communications in the M&P Division. I am confident that these seminars not only increase the knowledge base for the participants but also help them in networking, team building, and generating ideas for new research projects. Participants at a seminar share a common interest in the subject matter. This presents an opportunity for quality networking with other professionals in the same field.

Guest speakers were invited from both TTI and outside TTI, although the focus was to invite speakers from diversified backgrounds, i.e., industry, agency, private companies, and academia. Presenters from industry and agencies were significant in order to provide industry experience to the graduate students in this division. When topics of seminars overlapped with the other research divisions, I coordinated with these other divisions (i.e., Constructed Facilities) to enhance participation. Table 4.1 lists the speakers who presented seminars at the M&P Division Lecture Series. Some of these seminars generated very lively discussion/debate among the attendees. Besides these speakers, seminars were arranged and announced for at least five other guest speakers from industry who could not ultimately make it; seminars were canceled, or internal speakers were substituted.

TABLE 4.1 List of Speakers Who Presented Seminars

Name of Speaker	Topic of Seminar	Organization
Jeff Smith and Mark Belse, Sydney Cox	Use of Asphalt Rubber in Pavement Construction	Rubber Pavement Association, Cox Paving
Jim Moulthroup	Role of Consultants	Fugro, BRE
Billy Troxler	Evolution of Troxler, Inc.	Troxler, Inc.
Jay Winford	Business Aspects of HMA Paving	Prairie Construction
Jim Wright	Asphalt Emulsion	Akzo Nobel
Jo Daniel	Impact of Plant Production Parameters on Properties of RAP Mixtures	University of New Hampshire
Bob Klutz	Use of Kraton Polymer in Asphalt Mix, Especially in Porous Friction Course	Kraton Polymers U.S., LLC
Matt Corrigan	Warm-Mix Asphalt	FHWA
Bishwajit Bhattacharjee	Sustainability Performance Index for Concrete	Delhi Indian Institute of Technology
Audrey Copeland	Overview of the State of the Highway Construction Industry Including Current Issues, Economics, and Employment	National Asphalt Pavement Association
Christopher A. Jones	Working for Sandia National Laboratory	Sandia National Laboratory
Raj V. Siddharthan	Efficient 3D Dynamic Response Model for Layered Systems	University of Nevada, Reno
Amy Epps Martin	Academic Career and Family	M&P Division, TTI
Joe Zietsman	Sustainability in Transportation Development	Environmental Division, TTI
John Sedlak	High-Speed Rail	Rail Division, TTI
Gene Buth	Research in Safety and Structures	TTI (retired)
Dave Newcomb	Getting Your First Job after College	M&P Division, TTI
Graduate Students: Xue Luo and Yuqing Zhang	Characterizing Aggregate Anisotropy in HMA	M&P Division, TTI

I worked closely with Dr. Epps to make this seminar series a success. My responsibilities included inviting guest speakers, coordinating with other departments, preparing leaflets, emailing invitations to the attendees, and arranging logistics. Graduate students and administrative assistants supported me to carry out this task. I also coordinated the tour of the M&P Division's laboratory facilities for visiting speakers.

The most challenging task was to attain enough participation during the seminar, especially by full-time researchers and faculty. Often I had to encourage my colleagues over the phone and in person. I also assisted in arranging the seminar when another researcher/faculty invited a guest speaker. This effort was an excellent collaboration between TTI and the Civil Engineering Department of Texas A&M University.

I believe that this lecture series was a step in the right direction, although not enough to achieve the initial goal of enhancing internal communications. By volunteering for this task, I gained valuable experience in arranging seminars and enhancing communication skills in a research organization. This type of activity can also expose potential sponsors to the M&P Division's capabilities and facilities and thereby increase research funding.

CHAPTER V

TXDOT VISUAL DISTRESS DATA QUALITY MANAGEMENT

Background

In the last few decades, most state DOTs and other public highway agencies have adopted pavement management systems (PMS) to manage their pavement costs effectively (Flintsch and McGhee 2009). During the late 1980s and mid-1990s, under several directives, FHWA mandated that every state DOT develop its own PMS. The U.S. Department of Transportation defines a PMS as “a system that provides information for use in implementing cost effective reconstruction, rehabilitation, and preventive maintenance programs and results in pavement design to accommodate current and forecasted traffic in a safe, durable, and a cost-effective manner” (AASHTO 2001).

According to TxDOT, its PMS, known as the Pavement Management Information System (PMIS), is an automated system for storing, retrieving, analyzing, and reporting pavement condition information. Initially, TxDOT developed its first PMS called the Pavement Evaluation System (PES) in 1982. The primary objectives of the PES were to collect and monitor pavement condition data and help monitor the use of funds for pavement maintenance. TxDOT used the PES for almost 10 years with some modifications and upgrades until the PMIS was developed in 1993 (Zhang and Machemehl 2004). The PMIS was developed to retrieve and analyze pavement information to monitor pavement conditions; compare maintenance, rehabilitation, and reconstruction treatment options; perform funding allocations; and estimate total pavement needs. Besides aiding in pavement-related decision making, the PMIS is widely used in creating TxDOT's annual pavement condition report, known as the *Condition of Texas Pavements*. This report also serves as TxDOT's report card to Texas legislators.

PMIS Condition Score

TxDOT's pavement distress measurements for each PMIS section are combined and converted into a single distress score. A multiplicative utility analysis approach is used to calculate this score. By using a utility curve (sigmoidal or S shaped), each distress value is converted into a utility value between 0 and 1 (Scullion and Smith 1997). With a few exceptions like raveling and flushing, most of the distress types have a separate utility curve. This curve may be represented by the following equation:

$$U_i = 1 - \alpha e^{-\left(\frac{\rho}{L}\right)^{\beta}}$$

Where:

U = the utility value,

i = the pavement distress type (e.g., alligator cracking or concrete patch),

α = the horizontal asymptote factor controlling the maximum loss of utility,

e = the base of natural logarithms,

ρ = the prolongation factor controlling the length of the utility curve above a certain value,

L = the level of distress or loss of ride quality, and

β = a shape factor controlling how steeply utility is lost in the middle of the curve.

The PMIS distress score is calculated by multiplying all the utility values from each of the individual distress types for a given type of pavement. For example, the distress score for flexible pavement is calculated using following equation:

$$DS_{flex} = 100 \times [U_{SRut} * U_{DRut} * U_{Patch} * U_{Fail} \times U_{Blk} * U_{Alg} * U_{Lng} * U_{Trn}]$$

Where:

DS = the distress score,

flex = flexible pavement,

U = the utility value,

SRut = shallow rutting,

DRut = deep rutting,

Patch = patching,

Fail = failures,

Blk = block cracking,

Alg = alligator cracking,

Lng = longitudinal cracking, and

Trn = transverse cracking.

Distress utility scores for rigid pavements (both continuously reinforced concrete pavement [CRCP] and jointed concrete pavement [JCP]) are calculated similarly by multiplying the respective utility values of each distress for a given pavement type. TxDOT measures the roughness or ride value for 100 percent of its network of highways by using laser profilers. The ride value of each PMIS section is reported on a scale of 0 to 5. Again, the ride value is converted into a ride utility score ranging from 0 to 1. The final PMIS condition score for each section is calculated by combining both distress utility and ride utility scores, as shown in the following equation:

$$CS = 100 \times U_{DS} \times U_{RS}$$

Where:

CS = the condition score,

U = the utility value,

DS = the distress score, and

RS = the ride score.

PMIS Data Collection

Excluding some highway sections under construction, each year TxDOT collects pavement surface distress data on 100 percent of its roadbed mileage network. Pavement distress data are collected mainly using a manual windshield survey while driving along the side of the travel lane—when a drivable shoulder is available. Sometimes pavement raters walk along the side of the road when needed to verify or examine the distresses more closely. Pavement distress data are collected by private vendors September through January each year. Distress data are collected on the worst lane for multilane roadways and in both directions for divided roadways.

Table 5.1 shows TxDOT's current highway system summary. Under the PMIS, each year TxDOT collects the following network-level data from its highway system:

- Distress data, which describe the pavement's surface defects;
- Ride quality data, which measure pavement roughness;

- Deflection data, which measure the structural strength of the pavement section; and
- Skid resistance data, which measure surface friction using the TxDOT skid truck.

TABLE 5.1 TxDOT Highway System Summary

Description	**Length (Miles)**
Centerline miles	73,151.6
Roadbed miles	90,082.6
Lane miles	197,143.0
National Highway System lane miles	63,389.9

In the TxDOT PMIS, each pavement section is uniquely identified using the Texas Reference Marker (TRM) referencing system. In this linear referencing system, the TRM divides TxDOT highways and roadways into mostly 0.5-mile segments, all of which are identified by a combination of alphanumeric codes. These segments of highway are called PMIS sections. Sometimes PMIS sections can be as short as 0.1 miles or as long as 1 mile. After the corresponding district and county are specified, different highways are identified by their highway roadbed identification, a combination of letters and symbols that denote the highway system the highways belong to and the lane of interest. For example, “SH71 R1” refers to State Highway 71 and the southbound (or increasing TRM) rightmost lane of the main lanes. Finally, after the roadbed identification code, each individual PMIS section is uniquely identified by a set of four numbers: a beginning reference marker (and a corresponding displacement) and an ending reference marker (and a corresponding displacement) to define the section's location on a given roadway. An example of the complete designation of a PMIS section is "IH10 0242+00.5 0243+0.00 R2." A more detailed explanation about PMIS section designation can be found in TxDOT's *Pavement Management Information System Rater's Manual*.

Quality Assurance of Data Collection

Flintsch and McGhee (2009) mention that the collection of network-level pavement condition data, especially pavement distress data, is one of the most costly parts of operating a PMS. They also stress that the data quality has a critical effect on the business decisions supported by the PMS. Inadequate or flawed data in a PMS can cause erroneous or inappropriate pavement treatment options, or the poor data may not properly prioritize the sections in need of treatment or preservation. As a whole, incorrect decisions caused by poor data undermine the effectiveness of, and confidence in, the PMS. Flintsch and McGhee (2009) summarize the importance of data quality: "to effectively support the pavement management process, the data collection program collects, processes, and records data in a timely fashion, with a level of accuracy and precision adequate for decision being supported, assuring data consistency and continuity from year to year, and using a consistent location referencing system."

Highway agencies around the country are developing procedures and guidelines for managing the quality of pavement data collection activities to confirm the data collected meet the requirements of the pavement management process. The agencies using service providers to collect pavement condition data have developed systems for service provider selection, monitoring of data collection, data acceptance, and training. The agencies that employ in-house data collection have their own method of data quality management.

Scullion and Smith (1997) summarized the problems identified with the PMIS by conducting a statewide survey. The researchers identified one of the major concerns expressed by district personnel as the repeatability and consistency of the visual pavement condition data. Due to this concern, several districts were reluctant to use the system for its intended purpose. The district personnel also feared that the service providers hired for pavement condition data collection would operate on a production basis, causing the possibility of driving too fast and hence compromising the quality of data. In order to address this issue, Scullion and Smith (1997) suggested "developing a standardized auditing procedure to be implemented by district staff. This will include pre-rating of a set number of sections, comparison on ratings with pre-rated results and statistical criteria for acceptability. Contracts should be written to include this review and certification period."

Quality management of data collection is extremely important to achieve the desired goal of the PMS. Quality management of PMS data collection includes but is not limited to quality control (usually by the contractor), quality acceptance (by the agency), and an overall quality assurance plan implemented by the agency. Flintsch and McGhee (2009) defined quality acceptance as those activities conducted to verify that the collected pavement condition data meet the quality requirements and to ensure that the final product is in compliance with the specifications. The quality acceptance plan includes the establishment of acceptance criteria (e.g., data accuracy, precision, and reliability) and an appropriate sample size to examine whether the data meet these criteria. Some agencies incorporate independent assurance by using a third party to resurvey a sample of the data and compare the audit results to the production results (Flintsch and McGhee 2009). TxDOT's quality acceptance plan is somewhat similar to this.

TxDOT Pavement Distress Data Quality Management

TxDOT has been performing pavement surface distress data collection (PSDDC) since 1983 to determine the condition of the state highway network. Until 2001, TxDOT performed PSSDC in-house mainly using district employees. Since 2001, TxDOT has collected manual visual distress data on 100 percent of its roadbed mileage by hiring private contractors under PSDDC contract. During the same time, TxDOT signed an IAC with TTI to verify the quality of distress data.

TTI's Role in Distress Data Quality Management

The above mentioned IAC was set up to maintain the accuracy and consistency of distress data throughout the state and the consistency of data between different time periods. TTI's role is not as an independent third-party quality assurance provider. Rather, TTI employees and TxDOT district personnel jointly conduct a distress survey (audit) on sample PMIS sections. This audit is done in conjunction with a district representative to verify selected sections to assure the quality and accuracy of the PMIS data that have already been collected by the private contractors.

TTI provides an independent assessment of the data using personnel who are knowledgeable about Texas pavements, pavement distresses, and TxDOT's manual distress-rating procedures. Due to the relatively high turnover in district employees that perform PMIS audit functions, experienced TTI personnel help ensure consistency and uniformity in performing audits from district to district. TTI has provided PMIS audit services since the inception of the statewide, manual visual PMIS data collection effort started in 2001. This contract is renegotiated on a periodic basis, and cost increases since the beginning of this process in 2001 have been maintained at approximately 2 percent per year.

The PMIS audit process has identified sections of roadway and in some cases entire counties that needed to be re-rated. This process has helped ensure that PMIS manual visual distress data are maintained at a high level of accuracy. The contracted PMIS manual visual distress-rating process, in combination with the PMIS audit process, has helped improve consistency in PMIS data across all districts.

In support of the PSDDC statewide contract, TTI typically performs the following tasks to provide an independent audit of the contractors involved in the data collection:

- Attend PMIS visual rater certification classes,
- Attend regional pre-work meetings,
- Perform audits with district employees,
- Enter audit data and compare results with contractors' data, and
- Perform other tasks as required by TxDOT to verify data quality.

TxDOT has established a QC/QA program that is based on field surveys. All sections with distress ratings are eligible for audit. TxDOT uses a 10 to 12 percent random sample, by county, for approximately half of the counties in each district for the program. Typically, the other half of the counties in a given district are subjected to audit in the following year, but the same county can be audited in consecutive years. Selection of counties depends entirely on the discretion of the district PMIS coordinator. Sometimes the coordinator consults with TTI personnel before selection of counties. The district PMIS coordinator selects the counties to be audited but has the authority to reject data for any county that he or she contests. TxDOT rejects a county's data if the calculated distress score (based on all distress types except rutting) on audit sections differs from the rated sections by more than 15 points on more than 10 percent of the audit sections; rutting measurements are performed in-house.

The TxDOT Pavement Division, using a computer program, generates the audit sections for a given county based on the district's request. Typically, the audit sections include two to four adjacent PMIS sections randomly selected from the entire county covering approximately 10 to 12 percent of all PMIS sections for that county. Audit sections include PMIS sections with various distress levels based on the previous year's data. Sometimes the audit segment may include a lone PMIS section. Figure 5.1 shows a TxDOT-maintained highway network in Atascosa County with the audit sections shown in red. At the inception of this IAC between TxDOT and TTI, all counties were audited by sampling 5 to 6 percent of random PMIS sections, but the audit took much longer to complete because the auditors were driving too many miles to move from one audit section to another for every county. Later, at TTI's suggestion, TxDOT used half of the counties in a district with 10 to 12 percent random samples from each county.

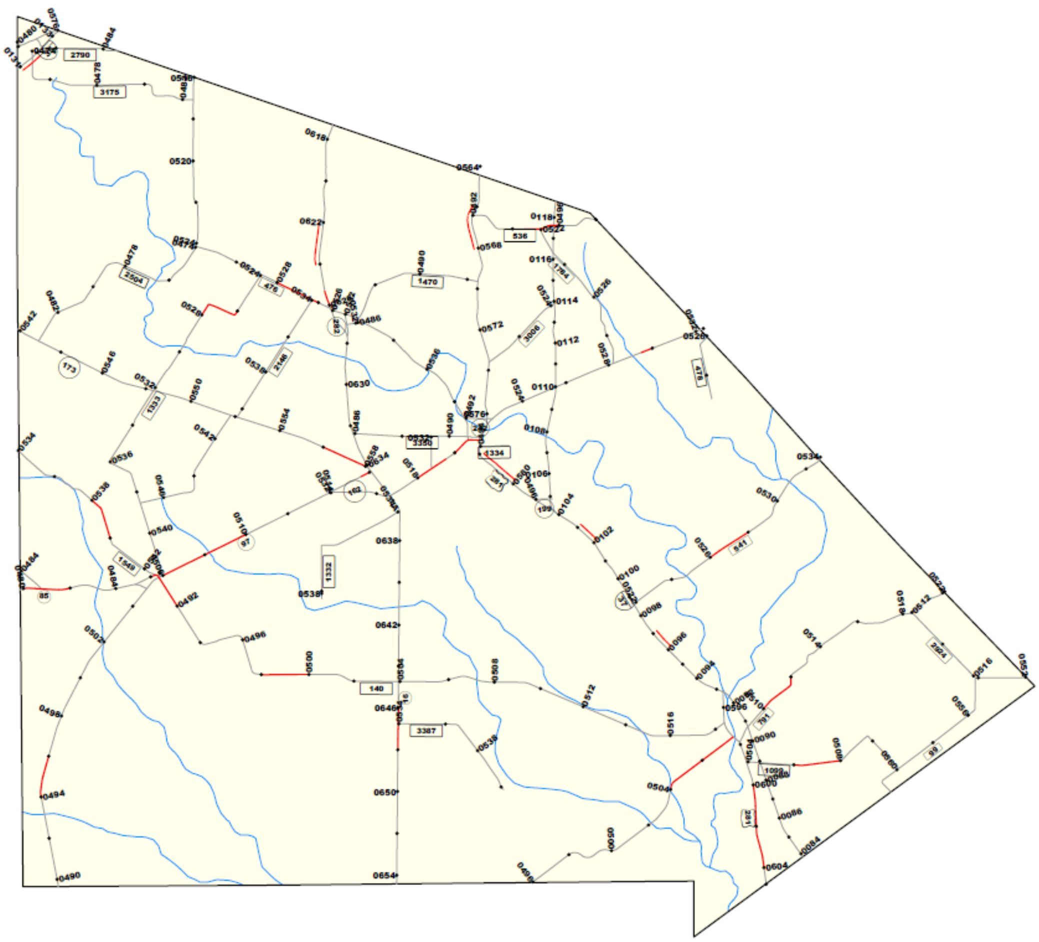


FIGURE 5.1 PMIS audit sections shown on Atascosa County map.

TxDOT Audit Clause in PSDDC Contract

TTI personnel follow the audit clause included in the PSDDC contract. The following includes excerpts from TxDOT's PSDDC contract related to data quality management:

AUDIT: TxDOT will audit PMIS sections for accuracy. At its discretion, TxDOT personnel will periodically accompany the PSDDC rating team during data collection to evaluate the vendor's equipment, procedures, and personnel. Additionally, a statistical sample of PMIS sections will be rated by TxDOT personnel and the results will be compared to the PSDDC team's data for accuracy and compatibility. Based on TxDOT's audit criteria (Attachment E), sections that do not meet the criteria shall be subject to re-collection at no additional cost to TxDOT.

REVIEW: Upon receipt of the required submittal from the vendor at the end of the PSDDC for each county, TxDOT will review the reports for completeness, accuracy, and compatibility. Refer to Attachment D – Region Work Plan/Data Collection Schedule.

APPROVAL: TxDOT will approve the completion of the PSDDC for each county within a region in writing. TxDOT approval of the submittal for each county will constitute approval of the PSDDC for that county; however, a written statement will constitute final approval for each PSDDC region.

TxDOT will audit (perform PSDDC) a statistical sample of PMIS sections for accuracy in selected counties.

SELECTION OF AUDIT SECTIONS: The audit sections will be determined by TxDOT personnel. Sections on which work has been performed by Maintenance forces between the vendor's PSDDC and TxDOT's audit PSDDC are excluded from the audit.

AUDIT PROCEDURE: TxDOT district personnel and University personnel will audit (perform PSDDC on) a sample of selected counties' PMIS sections and the results will be compared to the vendor's data for accuracy and compatibility. If more than 10.0 percent of the sections in any county audited by TxDOT have an absolute deviation of more than 15.0 points based on the modified distress score, the vendor shall be required to conduct new PSDDC for that county at no additional cost to TxDOT. The modified distress scores assume zero percent shallow and deep rutting. The audit results shall be final and binding.

If the submitted data fails the audit criteria, the vendor's team(s) in question shall stop all rating in other counties and re-rate the county(ies) that failed to meet audit criteria until all previously submitted data meet audit requirements. All re-rating must be complete and submitted by January 31 of the current fiscal year.

TxDOT Distress Data Collection

The PMIS contains more than 195,000 data collection sections, which combined make up the entire network of TxDOT's state-maintained highways (TxDOT 2012). Contractors collect the visual distress data of the entire network each year between September and January. While collecting the distress data, the raters travel along the side of the road at no more than 15 miles per hour and rate the most severely distressed lane.

Tables 5.2 and 5.3 present the distress types for flexible pavement (asphalt concrete pavement [ACP]) and rigid pavement (concrete), respectively, that the raters observe and measure for each PMIS section. Figures 5.2 through 5.4 show some typical distresses rated during this data collection season. Details about the rating procedure can be found in the *Pavement Management Information System Rater's Manual* (TxDOT 2012). Raters and auditors follow this manual during the distress data collection. Each summer, TxDOT provides the most updated and recent manuals to its raters and auditors. Raters and auditors record the measured distresses using the VISRATE computer program and/or using an automated rating sheet (paper copy). Either way, the data need to be entered into the TxDOT mainframe to calculate the distress score.

TABLE 5.2 Distress Types Measured in Visual Survey—Flexible Pavement

Name of Distress	Measurement Unit	Comment
Rutting—shallow (0.25–0.49 inches)	Percentage of total wheelpath length	Measured by automated vehicle
Rutting—deep (0.5–1.99 inches)	Percentage of total wheelpath length	Measured by automated vehicle
Patching	Percentage of total area of the section	
Failures (e.g., severe alligator cracking, large potholes, or rutting > 2 inches)	Number of failures	
Block cracking	Percentage of total area of the section	
Alligator cracking	Percentage of total wheelpath area of the section	
Longitudinal cracking	Linear feet per 100 ft of lane	
Transverse cracking	Number of full-lane width cracks per 100 ft of lane	
Raveling	Percentage of total area of the section	Does not affect condition score
Flushing	Percentage of total wheelpath area of the section	Does not affect condition score

TABLE 5.3 Distress Types Measured in Visual Survey—Rigid Pavement

CRCP	JCP
Spalled cracks	Failed joints and cracks
Punchouts	Failures
Asphalt patches	Shattered (failed) slabs
Concrete patches	Slabs with longitudinal cracks
Average transverse crack spacing	Concrete patches
	Apparent joint spacing

(Photo courtesy of TxDOT)

FIGURE 5.2 Distresses (alligator cracking) in flexible pavements.

(Photo courtesy of TxDOT)

FIGURE 5.3 Distresses (failures) in flexible pavements.

(Photo courtesy of TxDOT)

FIGURE 5.4 Distresses in concrete pavements.

Visual Rater Certification Classes

As part of the data quality management program, TxDOT's Pavement Division offers visual rater certification classes each summer. The objectives of these training classes are to teach how to rate and record distresses, update any change of rating procedure, maintain consistency in data collection across the state, and maintain consistency from year to year. Attendance at training classes and certification are mandatory for each person involved in data rating or auditing. TxDOT offers five separate classes for flexible pavements for five different regions of Texas. TxDOT also offers two certification classes for concrete pavements. New raters are required to attend a full three-day training class, and experienced raters can attend a one-day refresher course, held the final day of a three-day class, to obtain their certification.

Table 5.4 shows a typical agenda for the three-day training class. Typically, the auditors from TTI attend the full three-day classes in order to assist the TxDOT training coordinator and also to attend the pre-work regional meeting. During the training classes, the auditors from TTI assist the training coordinator in field ratings, discussions of rating experiences, and clarification of rating questions. I have noticed that several areas of improvement can be made in the rater's manual and the training process, which I conveyed to the TxDOT data collection coordinator.

Pre-work regional meetings during the training classes are held to clarify the plan for that year's data collection. The attendees of that meeting include the PMIS data collection coordinator from the Pavement Division (Mr. Marlon McGhee), the district PMIS coordinator, the contractor, and one auditor from TTI. Because I am responsible for coordination of the audit in the five southern districts in the south region of Texas, I attend the meeting held during the south region's training class. In these meetings, contactors usually submit their plan, list of personnel, and schedule for data collection following the deadlines set by each district. Attendees also discuss the performance of the previous year, any changes from the previous year, problems, and possible remedies. The TTI representative makes the plan with the district PMIS coordinator and contractor for auditing so that the audits are done in a timely manner. The audits of a county should be conducted within two weeks of the contractor's rating and data submission. A longer delay between distress ratings performed by the contractor and the auditor can cause significant differences in distress quantity in the same PMIS section.

TABLE 5.4 Typical Training Class Schedule

Tuesday Morning	Introduction
	PMIS Evaluation Process, Section Location
	Data Entry Forms
	Exercise, Locating Sections
Tuesday Afternoon	Pavement Distress Types
	Exercise, Distress Types
Wednesday Morning	Field Rating #1
	Review Ratings
Wednesday Afternoon	Field Rating #2
	Review Ratings
	Question & Answer Session
	Regional Pre-work Meeting, 3:00 p.m.
Thursday Morning	Rating Procedure Overview/Update
	Identification & Discussion of Rating Problems
Thursday Afternoon	Field Rating #3
	Review Ratings
	Conclusion, Questions & Answers, Certification Exam

TTI PSDDC Team

Headed by Mr. John Ragsdale, the TTI team includes four to five full-time employees and three to four part-time employees. Besides Mr. Ragsdale and me, the other full-time employees on this team were Mr. Tom Freeman and Dr. Andrew

Wimsatt. TxDOT divides its 25 districts into five regions for pavement visual distress data collection. The regions are:

- South region—San Antonio, Laredo, Yoakum, Corpus Christi, and Pharr;
- East region—Beaumont, Houston, Bryan, Lufkin, and Waco;
- Northeast region—Dallas, Paris, Atlanta, Wichita Falls, and Tyler;
- West region—El Paso, Odessa, San Angelo, Lubbock, and Austin; and
- Northwest region—Amarillo, Childress, Abilene, Brownwood, and Fort Worth.

I was responsible for the south region's visual distress data verification. I sometimes audited districts in other regions instead of certain districts in the south region due to schedule conflicts (audits had to be performed soon after the contractor submitted ratings). In cases when I was unable to perform the audit in my own area of responsibility, I found replacement auditors from different regions. Besides the southern districts, I audited entire or partial audit sections from other districts including Fort Worth, Dallas, Lufkin, Odessa, and Childress.

At the onset of the data collection season (September), the district PMIS coordinator and I met with the contractor's team responsible for rating in that particular district. This meeting was held to clarify the position of both parties and any special requirements for that district. This meeting was necessary, especially when there was a new rater's team working in a district or one of the team members was inexperienced. After the data collection started in September, the contractor sent status reports showing the progress in each county along with the plan for future work. As an auditor, I monitored the status reports carefully and coordinated with district PMIS coordinators for the audit schedule.

Auditing required me to travel extensively in different parts of the state for extended periods. Staying away from headquarters for prolonged periods posed different challenges in managing the other projects I was working on. Fortunately, technologies (i.e., a smart phone and the Internet) helped to mitigate this issue. Usually, the PMIS coordinator and I traveled in a TxDOT vehicle to audit sections (e.g., the audit sections shown in red in Figure 5.1) for rating. Sometimes more than one person from the district accompanied us for training purpose. I also provided hands-on training to the district employees who were inexperienced visual raters.

I was responsible for entering the data from each audit county using the VISRATE program, and then I handed over the data to the district coordinator. Later, the district coordinator input the distress data into the TxDOT mainframe to generate the distress scores. The mainframe computer generated a detailed comparison of distress scores between the contractor's scores and the auditor's scores. A typical comparison is presented in Figure 5.5. When more than 15 points of difference are noticed between the two scores, the contractor's rating of that score is considered failed. In other words, the difference should be no more than 15 to be considered a pass. The figure also shows the comparison of distress measurements by the raters and the auditors for each type of distress. Measurement of rutting (excluding failures or rut depth greater than 2 inches), which is measured in-house, is not considered in this comparison.

Figure 5.6 show a typical summary comparison of all audit sections of a county. This type of report shows the percentage of sections passed (or failed) for each pavement type (i.e., ACP, CRCP, or JCP) sections. In this case, the whole and/or audit sections did not have any concrete pavement. In order for the county or the rating data of a particular county to be acceptable, the total percentage of passing sections had to be 90 or above. If the county data did not pass the acceptance criteria, the contractor was required to repeat the rating immediately at no additional cost to the agency.

Before asking the contractor to repeat the rating of the whole county, usually the district coordinator and TTI auditors jointly reviewed the detailed report (Figure 5.5) to figure out the locations where the contractor made mistakes, or if there was any pattern of mistakes. It was very rare that the contractor had to repeat the rating of a whole county. In one instance, the PMIS coordinator and I had to meet the rating team to explain where they were making their mistakes.

Texas Department of Transportation

Pavement Management Information System (PMIS)

Annual Audit Detail Rating Comparison

Fiscal Year: 2012
Responsible District: Dallas (18)
County: Dallas (057)

Highway	Beginning Ref. Mkr.	Ending Ref. Mkr.	Sect. Len.	Pvmt. Type	Lane	Rating Type	Spl. Flj. Pat.	Pch. Fal. Fal.	Acp. Shs. Blk.	Pcp. Lng. Alg.	Spc. Pcp. Lng.	Ajs. Trn.	Dist. Score	Result
FM1382 K	0268 +00.0	0268 +00.5	0.5	08	1	Annual	000	00	000	001	015	01	100	
					1	Audit	000	00	000	000	030	01	100	
							0	0	0	+1	-15	0	0	Pass
FM1382 K	0268 +00.5	0268 +01.0	0.5	08	1	Annual	000	00	000	001	014	01	100	
					2	Audit	000	00	000	000	029	02	99	
							0	0	0	+1	-15	-1	+1	Pass
FM1382 K	0268 +01.0	0268 +01.5	0.5	02	1	Annual	002	000	000	000	000	15	100	
					1	Audit	002	001	000	000	006	15	86	
							0	-1	0	0	-6	0	+14	Pass
FM1382 K	0268 +01.5	0270 +00.0	0.5	02	1	Annual	000	000	000	000	013	15	58	
					1	Audit	001	000	000	000	002	15	100	
							-1	0	0	0	+11	0	-42	Fail
FM1382 R	0280 +00.0	0280 +00.5	0.5	02	1	Annual	000	000	000	000	000	15	100	
					1	Audit	002	000	000	000	000	15	100	
							-2	0	0	0	0	0	0	Pass
FM1382 R	0280 +00.5	0280 +01.0	0.5	02	1	Annual	000	000	000	000	001	15	100	
					1	Audit	002	000	000	000	000	15	100	
							-2	0	0	0	+1	0	0	Pass

FIGURE 5.5 Comparisons between rating and audit for different distresses.

Texas Department of Transportation

Pavement Management Information System (PMIS)

Annual Audit Broad Pavement Type Summary

Fiscal Year: 2014

Responsible District: Lufkin (11)

County: San Augustine (203)

Test: Percentage Passing the Rating Standard 90.00% of Sections with Distress Score (no rut) within ±15 points and Rating Dates within ±10 days.

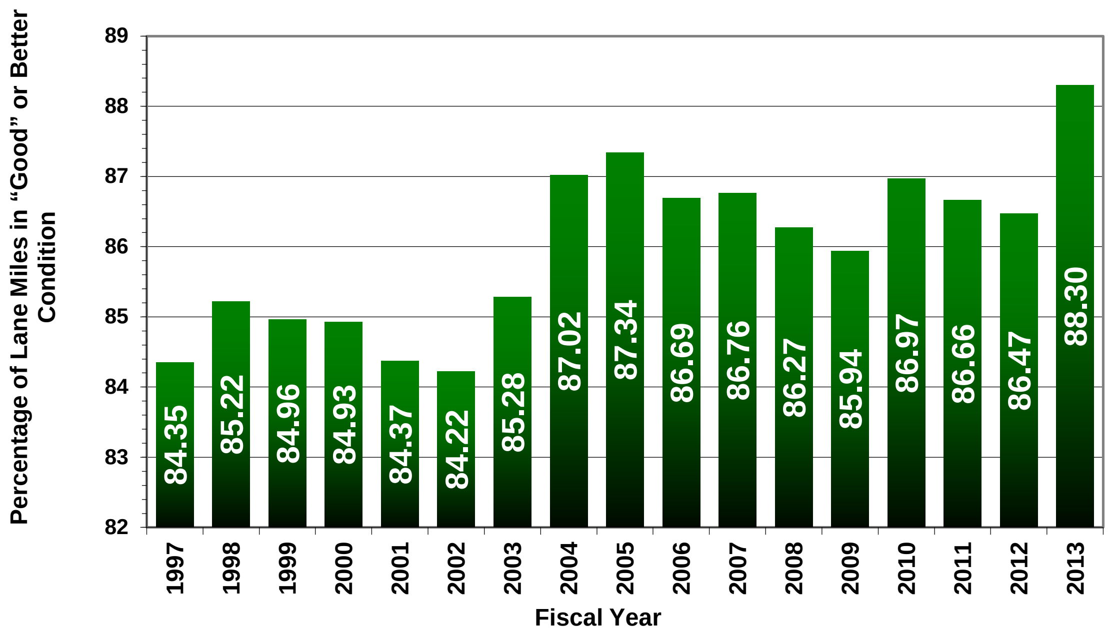
Pavement Type	Number of Sections				Percentage Sections Passing	Percentage Sections Rated
	Total	Rated	Passed	Failed		
ACP	57	57	52	5	91.23%	100.00%
Total	57	57	52	5	91.23%	100.00%

FIGURE 5.6 Typical audit report of distress scores for a county.

The audit team also reviewed the detailed reports even if the county's data were acceptable to see if there were any major errors. Based on this review, in a few instances the contractor was asked to re-rate certain parts of the county or certain parts of a highway to look for specific types of distresses that they missed or overestimated. Besides the pass/fail of audit sections, the district coordinator checked the overall data submission, production rate, daily reports, etc.

Special Tasks

Per the IAC, the TTI team performed additional duties as requested and directed by TxDOT personnel for the purpose of data quality management. In fiscal year 2013, the TxDOT Pavement Division noticed significant improvement of condition scores compare to the previous year throughout the state, as shown in Figure 5.7 (Texas Department of Transportation 2014).



(Graph courtesy of TxDOT)

FIGURE 5.7 Condition score of pavements in Texas.

Initially, the TxDOT personnel were skeptical and asked the TTI team to examine the data to find the cause of the sudden condition improvements. Under Mr. Tom Freeman's leadership, the team analyzed the distress scores and condition scores from the pavements in most of the 25 districts in Texas. The team analyzed the last 12 years' data starting from 2001. Plots were prepared for each distress type including the ride score against the time period for each district. An example of a plot is shown in Figure 5.8 where the ride score shows a relatively flat line.

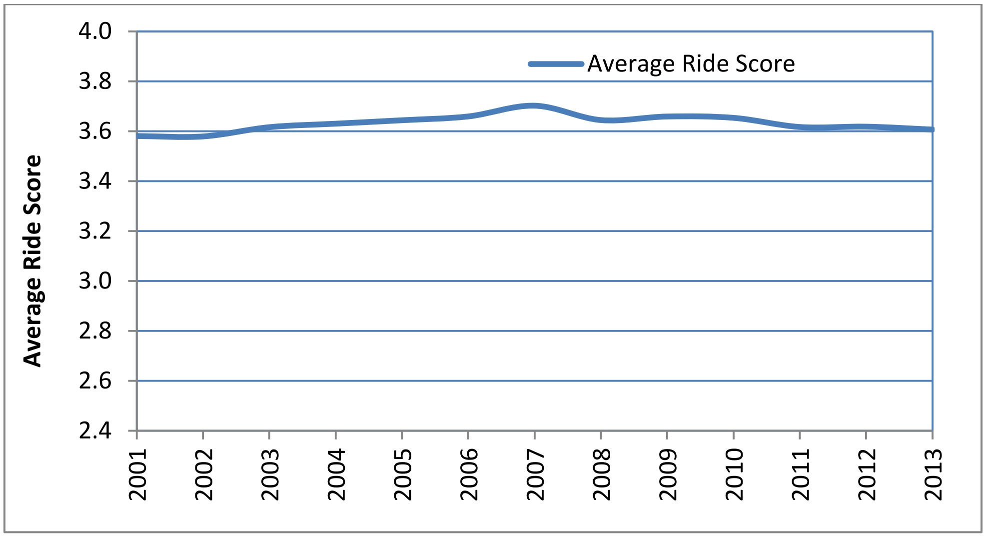


FIGURE 5.8 Average ride score of pavements in Odessa.

Analyses using individual distress types did not reveal any specific pattern, but when the team superimposed the district's maintenance expenditures on top of the average distress score or average condition score, it revealed the pattern shown in Figure 5.9. Other districts showed similar patterns where the distress score and condition score improved with increased maintenance expenditure. A short lag time occurred between the increased maintenance expenditure and improved distress score.

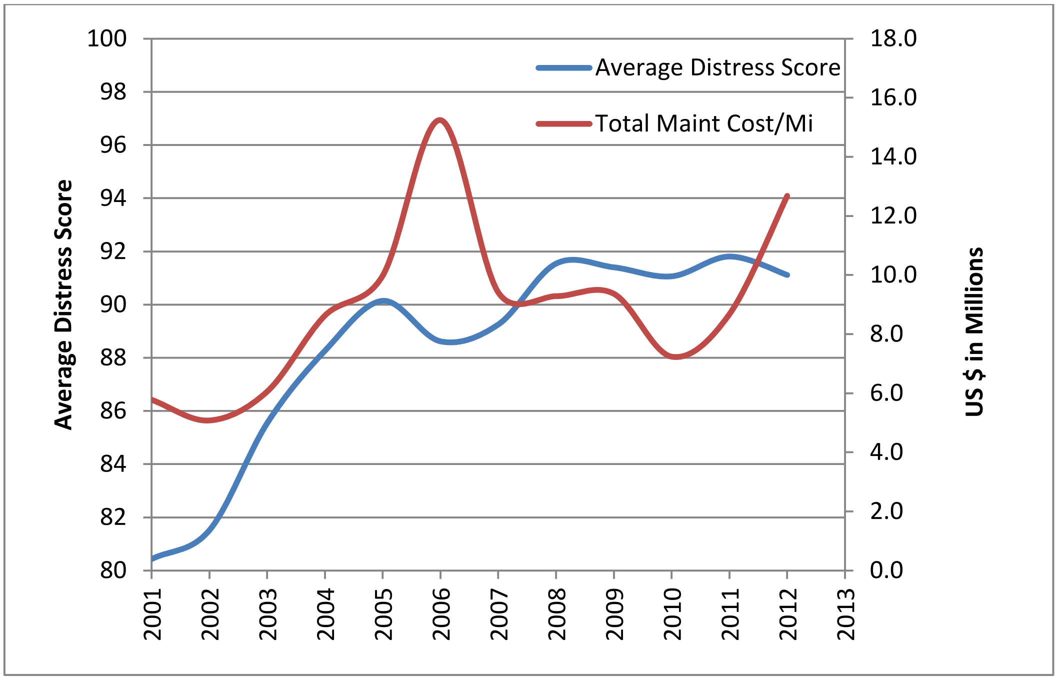
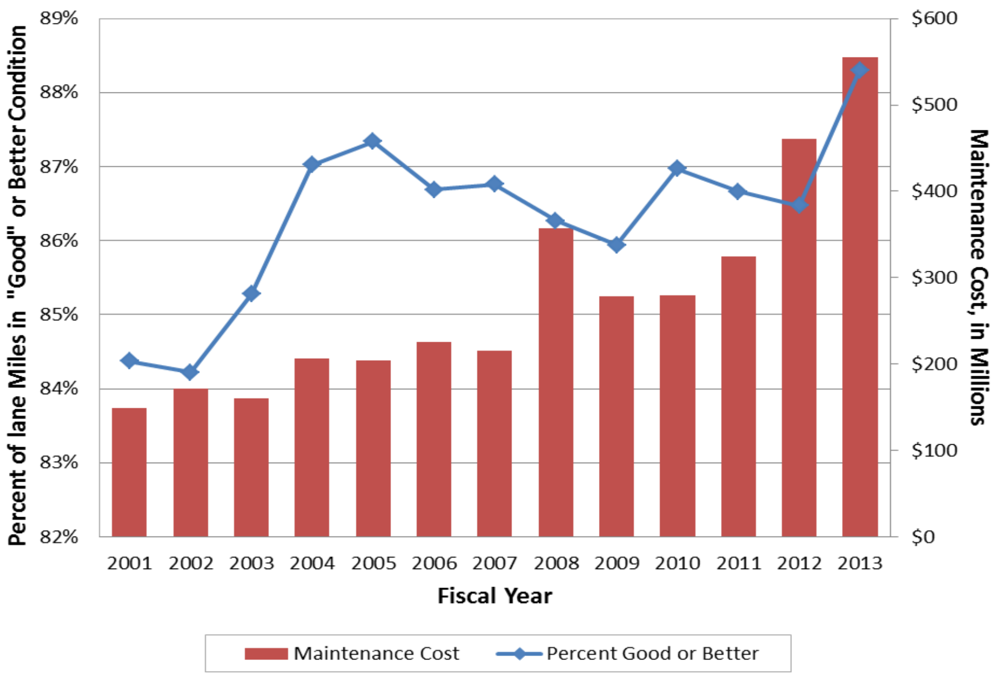


FIGURE 5.9 Shifting distress score with maintenance cost (Dallas District).

The same trend was captured when the distress score was compiled with the statewide condition score presented in Figure 5.10. This result was presented to TxDOT to assure that the data quality of last year was no different from previous years, and there was an explanation for the sudden rise in condition scores. Despite this phenomenon, I understand that a dramatic rise in condition score may not be sustainable if it is done only through an increase in pavement maintenance activities. From my experience of auditing, I learned how easily one can improve the condition score of the district for a short period by repairing failures and making the patches full road bed with a minimum length of 500 ft. The real challenge is making the improved condition score sustainable over the years.

Along with periodic maintenance, pavements need appropriate rehabilitation, reconstruction, preservation, and better construction practices for sustainable higher condition scores.



(Graph courtesy of TxDOT)

FIGURE 5.10 Shifting distress score with maintenance cost for the entire state.

At different times, I made some recommendations to TxDOT to improve the overall data quality management. I suggested making some changes in the field rating during the training class. Earlier, all the participants drove along the side of the road and rated the entire half-mile section through a windshield survey for a few sections and later compared the results among different teams including the instructor. Obviously, there were huge differences in distress measurements. Because of the nature of this rating, this method increases subjectivity, and the participants could not effectively identify where they were making mistakes. My suggestions included comparing the results after each PMIS section when their memories were fresh. Another suggestion was that the participants walk along the roads for relatively short distances (i.e., 500 feet), when conditions are safe, and then compare the results immediately so that the participants can identify whether they are missing any distress, misidentifying any distress, or overestimating or underestimating the extent of distresses. A shorter distance provides the advantage of being able to look back at the distresses.

I believe that the pass/fail criterion of a 15-point difference in modified distress scores on more than 10 percent of the audit sections is a little too lenient. The allowable difference in distress scores should be less for pavements with relatively good condition. In other words, there should be more than one criterion depending on the conditions of pavements. I observed that even after making many mistakes in rating, a rater can have a difference of less than 15 points in distress scores, especially in relatively good PMIS sections. This advantage leads the raters to drive faster to increase their productivity, which in turn can cause either misidentification of distresses and/or underestimation of distresses.

I also identified some inconsistencies in the rater's manual and some areas that do not cover all possible situations that the raters might find on pavements. I reported those to the training instructor to update the manual in its future edition. One such example is presented in Table 5.5. The current definition of a pothole presented in the rater's manual does not cover all possible situations.

TABLE 5.5 PMIS Pothole Definitions

Width/Length (Diameter)	**Depth**	**Surface Type**	**Base Exposed**	**Distress Type**
Any size	0″–2″	Thin surface treatment	Exposed but in good shape	None
4″–12″	0″–2″	Thin surface treatment	Exposed and in poor shape	Small pothole
12″ or greater	0″–2″	Thin surface treatment	Exposed and in poor shape	Failure
Any size	0″–2″	Any	Not exposed	None
4″–12″	2″ or greater	Any	Any	Small pothole
12″ or greater	2″ or greater	Any	Any	Failure

Lessons Learned

This project was an excellent opportunity for me to learn and practice the nontechnical skills required to be an engineering manager, and to increase my technical knowledge. Auditing of an entire state was possible because of good teamwork. Time management was an issue because the audit had to be completed in a timely manner without jeopardizing other projects in hand. This project also taught me ways to handle large data. Reviewing the work of contractors, especially in cases of rejection, allowed me to gain experience in quality assurance.

Working on the project provided me with knowledge of network-level distress quality management. For personal interest, I studied the data quality management techniques employed by other state DOTs. Working on this project also made me curious to study different types of data collection techniques; the advantages and disadvantages of automated, semi-automated, and manual distress rating; and their cost comparisons. Due to the extended travel required for this project, I developed skills for remotely managing projects.

CHAPTER VI

SUMMARY

This ROS describes my professional engineering experience during my internship period under the DEng program while serving as an assistant research engineer in the M&P Division of TTI. I worked on a variety of projects in the M&P Division during this period and served as PI, as co-PI, and in support roles in these projects. I chronicled two major projects and the professional development activities that I participated in. I also briefly described three other projects where I was in charge of field testing and sampling. While describing the details of my activities, this ROS also shows how I fulfilled my learning objectives set at the beginning of the internship. The objectives of my internship, for partial fulfillment of the DEng program requirement, were to enhance my ability in project management, organizational communication, and quality management of pavement condition data; attain professional development; and assist to fulfill TTI's mission. This ROS also describes TTI's history, mission, organizational structure, and M&P Division.

The training project in Kosovo enabled me to apply my knowledge and experience in pavement design and highway construction. The project also enhanced my knowledge in this field and improved my expertise in developing and delivering training courses. Through this training program, I was able to apply my knowledge of cross-cultural diversity that I learned from management courses taken at Texas A&M. Because of my prior experience of working in another developing country, I could practice my skill of working and having interaction with people from different countries, languages, and backgrounds. Developing and delivering these courses under a relatively tight schedule and maintaining the standards of different organizations helped me develop new managerial and communication skills.

Delta-T leadership training taught me how to develop the leadership skills required in personal, professional, and volunteer environments; and how to strengthen my ability to manage and lead at TTI. Working on the project to improve TTI's deliverables, I worked in a large team comprised of people from different professions and academic backgrounds. The team looked at ways current technologies could be used to enhance project deliverables and documented possible enhanced deliverable implementation ideas in the deliverables matrix. The team prepared a prototype web-based enhanced deliverable with cost analysis. Additionally, the team recommended that TTI form an implementation team to further develop the concept of enhanced project deliverables.

Since transportation workforce development through training is one of TTI's core businesses, the instructor development training offered by NHI provided significant professional development for me. Through this training, I boosted my knowledge and skills as an effective instructor. The time management and organizational skills workshop also enriched my ability to manage multiple projects, and meet deadlines using available resources and while maintaining a balance between professional work and personal life. By coordinating the lecture series at the M&P Division, I gained valuable experience in arranging seminars, enhancing communication skills in a research organization, and collaborating with other departments.

TxDOT's visual distress data audit was an excellent opportunity for me to learn and practice the nontechnical skills required to be an engineering manager and to increase my technical knowledge. Excellent teamwork helped accomplish the challenge of auditing data for the entire state of Texas. Time management was an issue because the audit had to be completed in a timely manner without jeopardizing other projects in hand. This project allowed me to learn quality management of data collection and the handling of large data. Reviewing the work of contractors, especially in the cases of rejection, allowed me to gain quality assurance experience.

I gained very useful experience in the coordination of multiple groups from different organizations while working on the field projects. Those field projects also helped me practice safety protocols and my communication skills.

I have experience working as an engineer in public, private, and academic environments. At TTI, I had managerial experience while working as a PI and laboratory supervisor of the M&P Division's McNew Research Laboratory. I completed 48 credit hours of courses at Texas A&M from a wide variety of disciplines that taught me the necessary technical and nontechnical knowledge required to be a successful engineering manager. I applied some of this newly learned knowledge while working at TTI. Considering the technical, nontechnical, and managerial knowledge and skills gained through working on these projects and professional activities, I believe that I met the objectives of my internship and thus the objectives of the DEng program.

REFERENCES

American Association of State Highway and Transportation Officials (1998). *Guide for Design of Pavement Structures*, 4th edition. Washington, D.C.

American Association of State Highway and Transportation Officials (2001). *Pavement Management Guide*. Washington, D.C.

Flintsch, G., and K. K. McGhee (2009). *Quality Management of Pavement Condition Data Collection. A Synthesis of Highway Practice.* NCHRP Synthesis 401, Transportation Research Board, Washington, D.C.

National Highway Institute (2000). *The Circle of Learning.* Publication No. FHWA-NHI-00-047, Federal Highway Administration, Washington, D.C.

National Highway Institute (2014). Instructor Development Course (3.5-Day). http://www.nhi.fhwa.dot.gov/training/course_search.aspx?tab=0&key=420018&course_no=420018&res=1.

Rockhurst University Continuing Education Center, Inc. (2010). *Time Management and Organization Skills. A Workshop for Agriculture and Engineering Programs.* Overland Park, Kansas.

Scullion, T., and R. Smith (1997). *TxDOT's Pavement Management Information System: Current Status and Future Directions.* Report 0-1420-S, Texas Transportation Institute, College Station, Texas.

Texas A&M Transportation Institute (2013). *Texas A&M Transportation Institute—Over 60 Years of Innovation.* College Station, Texas.

Texas A&M Transportation Institute (2014). Website. http://tti.tamu.edu/.

Texas A&M University (2009). *Doctor of Engineering Graduate Program Manual.* The Dwight Look College of Engineering, College Station, Texas.

Texas Department of Transportation (2012). *Pavement Management Information System Rater's Manual*. Austin, Texas.

Texas Department of Transportation (2014). *Condition of Texas Pavements. Texas Department of Transportation PMIS Annual Report FY 2010–2013.* Austin, Texas.

Texas Transportation Institute (2010). *Texas Transportation Researcher*, Vol. 46, No. 4.

Zhang, Z., and R. B. Machemehl (2004). *Pavement-Related Databases in TxDOT*. Report 0-4186-3, Center for Transportation Research, Austin, Texas.

APPENDIX

EVOLVING OUR RESEARCH DELIVERABLES: DELTA-T TEAM REPORT

Evolving Our Research Deliverables:

DELTA-T 2011 Team Report

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April 2012

TEXAS A&M TRANSPORTATION INSTITUTE

THE TEXAS A&M UNIVERSITY SYSTEM

Introduction

The traditional outcome of most research projects is disseminated in a written report that documents the research methodology and results. This deliverable format does not always maximize available technologies nor does it promote broad-range information sharing to an audience that may include future research sponsors. The 2011 DELTA-T team (the team) believes that researchers should maximize the value of project deliverables including usability, timeliness, and use of highly-interactive features and information sharing techniques that are available through recent technological enhancements. Proper enhancement of project deliverables would have significant benefits, including the promotion of past and current research and potential growth in the TTI research program.

This project examines the current state of project deliverables as well as potential enhancements that could be made, keeping in mind that any changes should integrate smoothly with current research activities while also expanding appeal to additional types of potential users outside the traditional research community.

Problem Statement

"Investigate the effectiveness of the traditional project report as a deliverable and assess the need for either new or alternative formats." Researchers involved with this project want to explicitly state that the scope of the project is not to replace traditional written report deliverables but to provide alternative value added information delivery formats and enhancements to better serve sponsors and TTI.

Literature Search Findings

The DELTA-T team identified the following key characteristics to successful project deliverables:

- A communication format that is engaging to the user.
- There are useful outcomes presented.
- Broad dissemination of the results is achieved.

With these characteristics in mind, the team provided a list of options available for consideration as deliverable dissemination tools:

- listservs,
- blogs,
- internet forums,
- wikis,
- videos,
- quizzes,
- presentations in workplace and academic conferences,
- seminars, webinars, workshops, and podcasts,
- executive summaries,
- research summary document (key findings and fact sheets),

- media coverage (newspapers, television, and radio; work with office of public affairs or communications),
- press releases,
- policy briefings,
- flyers, brochures, and research briefs,
- newsletters,
- reports to your funding agency,
- project website or internet/intranet,
- databases and search engines, and
- libraries and clearinghouses.

The team also examined what standard principles are considered good business practices, as these principles are indicators of effective presentation. The following list highlights the most common of these principles:

- involve communication professionals,
- understand the audience,
- demonstrate a tangible benefit,
- recognize that timing is relevant,
- build coalitions,
- build two-way relationships, and
- tailor packaging.

Current Usage of Project Deliverables

Currently, there are approximately 3,800 PDF reports and ZIP files (containing work product) posted on the TTI website. In order to gain a better understanding of the utilization of these resources, the team assessed the amount of web-related traffic that is attributable to research results that are posted online. The monthly total number of unique pages viewed and the total number of page views is provided in Figure A1.

For example, a total of 80 pages were viewed in October 2011, and those same 80 pages had 214 total views.

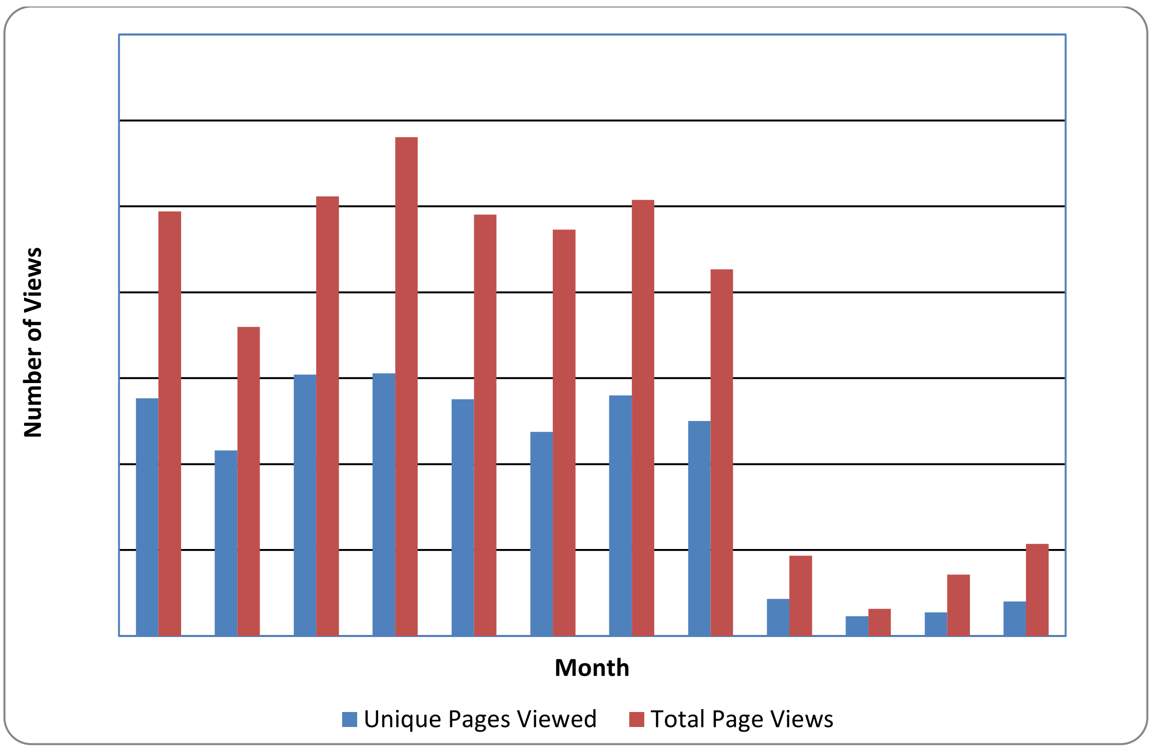


FIGURE A1 Summary of page views of TTI reports.

From November 2010 through October 2011, there were approximately 8,300 views of 1,837 different report pages. That is, nearly one-half (48 percent) of all the reports currently hosted on the TTI website were accessed at least one time during the past year. The ten most viewed reports from November 2010 through October 2011 are shown in Table A1.

TABLE A1 Most Viewed TTI Documents (November 2010–October 2011)

Report Name	**File Name**	**Number of Views**
2010 Urban Mobility Report	mobility_report_2010.pdf	154
2009 Urban Mobility Report & Appendix	mobility_report_2009_wappx.pdf	96
2007 Urban Mobility Report	mobility_report_2007_wappx.pdf	86
Abandoned Rail Corridors in Texas: A Policy and Infrastructure Evaluation	0-6268-1.pdf	46
The Development of the Interstate Highway System in Texas	TTI-2006-8.pdf	43
Traffic Operational Impacts of Transverse, Centerline, and Edgeline Rumble Strips	0-4472-2.pdf	35
Evaluation of Barriers for Very High Speed Roadways	0-6071-2.pdf	32
Urban Intersection Design Guide	0-4365-P2.pdf	31
Guidelines for Designing Bridge Piers and Abutments for Vehicle Collisions	9-4973-2.zip	31
Dynamic Message Sign Message Design and Display Manual	0-4023-P3.pdf	30

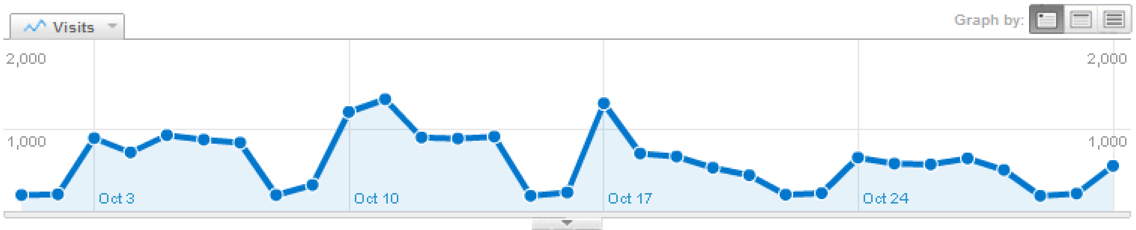
While the number of pages viewed and the total number of times those pages are viewed are useful statistics, they do not provide a thorough overview of the audience accessing the information. Analytic tools allow for the tracking of service providers that access a particular website. While there are thousands of internet service providers (ISPs), the focus of ISP analysis is to ascertain the amount of traffic attributed to TTI (via Texas A&M University) and TxDOT. Figure A2 provides an example of ISP summary statistics that can be generated. Based on Figure A2, it is important to note that the average time spent viewing the TTI website was less than three minutes. This highlights an important fact when considering how information should be delivered – quickly and easily understood.

The caveat with these data is that they are compiled for the TTI website as a whole, not specifically for those pages that contain links to reports.

Overview »

Service Providers

Oct 1, 2011 - Oct 31, 2011



18,725 visits came from 3,327 service providers

Site Usage | Goal Set 1 | Views:

Visits	Pages/Visit	Avg. Time on Site	% New Visits	Bounce Rate
18,725	**3.76**	**00:02:51**	**64.14%**	**51.05%**
% of Site Total: **100.00%**	Site Avg: **3.76 (0.00%)**	Site Avg: **00:02:51 (0.00%)**	Site Avg: **64.15% (-0.02%)**	Site Avg: **51.05% (0.00%)**

	Service Provider (None)	Visits	Pages/Visit	Avg. Time on Site	% New Visits	Bounce Rate
1.	texas a&m university	**2,140**	3.57	00:02:19	50.56%	52.52%
2.	texas department of transportation	**1,841**	7.45	00:06:06	21.29%	25.48%
3.	road runner holdco llc	**939**	3.54	00:02:43	70.61%	48.78%
4.	suddenlink communications	**893**	3.33	00:02:47	62.04%	58.79%
5.	verizon online llc	**506**	3.42	00:02:01	68.38%	52.17%
6.	comcast cable communications inc.	**477**	2.93	00:02:10	75.89%	55.77%
7.	at&t internet services	**441**	3.31	00:02:09	69.16%	54.65%
8.	service provider corporation	**430**	1.81	00:01:05	70.23%	71.86%
9.	tw telecom holdings inc.	**211**	4.17	00:03:56	49.76%	43.13%
10.	cellco partnership dba verizon wireless	**170**	2.51	00:02:11	60.00%	58.82%

Filter Service Provider: containing | Go | Advanced Filter | Go to: 1 | Show rows: 10 | 1 - 10 of 3,327

FIGURE A2 Example of service provider summary statistics.

It is highly likely that some of the visits to the TTI website from certain ISPs (e.g., Suddenlink, Verizon, and Comcast) are attributed to TTI employees accessing the websites from remote locations, such as their home or from a hotel while traveling. Unfortunately, there is no exact way to make a distinction in the analysis. Despite that, the team is interested in ascertaining how many visitors to the TTI webpage utilized the TAMU and TxDOT ISPs. The thousands of other ISPs are grouped into an "Other" category. Table A2 provides the results of this review in a month-by-month.

The results show the total number of visits by the three categories of ISPs, as well as the percent of total visits for each ISP group. Additionally, the average number of pages viewed per visit is provided. For the period from November 2010 through October 2011, 9% of the visits were from the TAMU ISP and 5% were from the TxDOT ISP.

TABLE A2 Summary of ISP Statistics

Month	Number of Visits				Percent of Total			Pages/ Visit
	TAMU	TxDOT	Other	Total	% TAMU	% TxDOT	% Other	
Nov-10	1,559	600	18,270	20,429	7.6	2.9	89.4	3.28
Dec-10	1,153	566	15,297	17,016	6.8	3.3	89.9	3.46
Jan-11	1,871	426	20,877	23,174	8.1	1.8	90.1	3.27
Feb-11	1,696	553	16,389	18,638	9.1	3.0	87.9	3.33
Mar-11	1,782	473	18,076	20,331	8.8	2.3	88.9	3.42
Apr-11	1,850	353	18,542	20,745	8.9	1.7	89.4	3.33
May-11	1,459	347	15,621	17,427	8.4	2.0	89.6	3.13
Jun-11	1,561	722	15,166	17,449	8.9	4.1	86.9	3.35
Jul-11	1,260	564	11,749	13,573	9.3	4.2	86.6	3.4
Aug-11	1,426	1,124	10,563	13,113	10.9	8.6	80.6	3.81
Sep-11	1,809	2,138	12,105	16,052	11.3	13.3	75.4	3.95
Oct-11	2,140	1,841	14,744	18,725	11.4	9.8	78.7	3.76
Total	**19,566**	**9,707**	**187,399**	**216,672**	**9.0**	**4.5**	**86.5**	**3.46**

Project Methodology

As a first step to gather information for this project, the team held a brainstorming session to identify questions that would be used to interview interested parties and gather both TTI and sponsor perspectives. The results of these interviews provide evidence as to what TTI's current audience is looking for from a project deliverable as well as how that audience might be expanded. The following questions were used as a basis for guiding the interviews:

- How do you perceive current TTI project deliverables?
- Do you believe there is anything missing from current project deliverables? If yes, what?
- How would you improve project deliverables?
- What formats would you consider for enhanced forms of project information distribution?
- How should enhanced deliverables be marketed?
- Is this something TTI should spend resources on?
- How should enhanced deliverables be funded?

Once the interviews were complete, the team compiled the common ideas and needs that were identified and looked at how these could be addressed through the enhancement of the deliverable framework. From this, a deliverables matrix was developed to better define how and when different enhanced deliverables should be considered for use. Additionally, the team developed examples of new deliverable formats and created example cost estimates for the enhanced deliverables.

Summary of Interviews

Prior to evaluating and recommending new deliverable formats, the team deemed it necessary to obtain a broader perspective on how current deliverables are viewed by various end users of TTI's research. The team wanted to find out the shortcomings of existing deliverable types and the needs that new deliverable formats should satisfy. To accomplish this, the team conducted interviews of several senior-level personnel within and outside TTI.

The interviews focused primarily on obtaining views on the effectiveness, or lack thereof, of existing research report style deliverables. Information was gathered about the potential end users of TTI's research and the groups that fail to benefit from the existing deliverable format. The interviews also gathered information on formats or features that are needed or can be improved with new deliverable types.

Current shortcomings of deliverables

The audience for research reports crosses numerous disciplines, backgrounds, and levels of experience. End users of any research product can be fellow researchers, academicians, practitioners in the private sector, DOT and federal employees, the public, executives, and politicians. Politicians are particularly keen on having succinct and readily available answers.

Standard project deliverables are usually reports written by engineers, for engineers, and thus tend to be too technical and boring for other types of end users. Based on the informal interviews conducted by the team, a large majority of the targeted audience is not interested in or willing to spend considerable amounts of time reviewing a large research report. Most end users of the research need answers to be more readily accessible and easily understood. Thus, deciphering large amounts of information is simply not justifiable given existing commitments and demands for time.

While current product deliverables may focus on catering to existing sponsors, providing new deliverable formats that are appropriate for a wider range of research end users is important for marketing future research and building new sponsor relationships. Many sponsors desire web-based content and training materials, webinars, and software as deliverables. It is important to consider the non-engineer audience that may be reading the reports and making business decisions for a potential sponsor; or the politician that quickly needs to locate certain facts or needs to see the value of the resources spent on research.

It is important to realize the difference between *passive delivery* of information (e.g., reports) and *active delivery* of information (e.g., webinars, videos, and interactive deliverables). Researchers are typically not equipped to handle the latter (e.g., producing a narrative to a video). The paradigm change will need to involve additional people with appropriate skills needed for active delivery of information, such as information technology specialists, learning specialists, and communication experts.

The team also found that after face-to-face personal relations, the most common way potential new sponsors find TTI researchers and experts is via internet searches and content or reports available through sources such as NCHRP. As a result, it is important to provide good information about TTI's research online and in formats that are easy to access and collect information from.

What is needed from deliverable formats

The overwhelming need from new deliverable formats is to provide key research information in a quick manner that is presented in a format simple enough to serve the needs of a non-engineer and that helps with implementation in the real world. The deliverable should be interesting and have a “wow factor” for the end user. However, one size does not fit all; deliverable options should be selected keeping in mind the potential end users and nature of the project. Given a wide range of variables, one specific deliverable format may not be adequate for all circumstances.

Several key points regarding the necessities of new deliverable formats were cited during the interview process, as follows:

- A web-based searchable research report clearinghouse to find needed information quickly.
- Ability to display information quickly to evaluate it for implementation.
- Currently, there is no easy way to implement the findings of a research report and apply them in real world. More work is needed to provide people with an easy way to implement the results and findings.
- Results of research should be geared toward the audience. TTI may need different tiers of information based on the potential audience.
- Ability of pulling important points from the report rather than overwhelming the user with a lengthy document.

- Question driven products can be beneficial. For example, products that can provide answers to potential user questions such as “What is the best way to do xyz?”
- There are also more requests for products that are directed to field personnel—manuals, ‘how-to’ material, etc.
- Products that tell a better story of what we do at TTI and to awe potential users.
- Web based content, which is compliant to state and federal requirement on web contents (e.g., 508 compliance).
- Improvements could be made in graphics, multimedia, packaging, and presentation.

Implementation ideas

Several key points regarding implementation were mentioned during the interview process, as follows:

- Modernization of the executive summary is a place to start.
- Putting out research summary sheets on the web consistently for all projects will be helpful.
- For almost every project, researchers give presentations to sponsors and to many committees and organizations. These presentations (PowerPoint with Audio) can be recorded and turned into videos, which can be available online, i.e., produce audio over pictures/slides.
- Researchers could do a webinar for their research, which is again a basic presentation covering the research performed and taking any questions from the attendees. Such

webinars may not be heavily attended, but they can be recorded and placed online. This will also get more attention on the web and will summarize the key aspects of research in a more interactive manner.

- Large project meetings where travel is necessary are often difficult to coordinate which results in a long time between interactions with the researchers. Consider utilizing tools such as webinars to present research milestones.
- Many clients ask for trainings or other means of learning in their area. This is again something where recorder presentations and webinars could be useful.
- Possibly send webinar progress reports. Video chat with panel or leave a video update that they can respond to but don't have to view real time. Webinar model shows there is value to having the talking head with the slides or notes.
- Produce 10-30 second sound bites or podcast summaries that can be available for download for mobile listening.
- Research reports should be online and more interactive with hyperlinking and drill-down capabilities. Use existing online magazines for examples of how to do this.
- Develop taxonomy link of relevant terms or concepts.
- Visibility on the web and tagging reports properly may be a key to getting the attention of new clients.
- Utilize video to put PIs in front of the camera to add emphasis to what our groups do, as well as to highlight TTI's expertise. Project footage and general video summations of PI and division would certainly add another layer.

- 1-page and 4-page summary reports: The 4-page summary is the more productive option. It provides enough details and is easy to present/deliver.
- Answer the question "How does the research relate to somebody's everyday experience?"
- Answer the question "How is research being consumed now? Online? In print? Not at all?"

Funding considerations

TTI must consider both the cost to funding new deliverable formats and the potential benefits of each. The following ideas were noted:

- There should be a pilot period for a year to see what can be accomplished with the understanding TTI would commit a stated sum of resources. TTI could look for other sponsors, such as TxDOT, to match TTI's funding for the pilot program.
- It will be difficult to charge sponsors in the early stages. However, sponsor feedback would be an important part of the overall success of the pilot program. When sponsors see value to this program, future sponsor funding will be possible.
- Every TxDOT project is required by TxDOT to have a project summary report (PSR) according to the contract deliverables table.
- Video summary report (VSR) is currently produced by TTI Communications using an Implementation Support Contract. Communications is currently required to keep the cost of producing a VSR around $2,500.

Examples of Enhanced Deliverables

Technical details

Technology is the driving force behind many of the potential innovations for TTI project deliverables. The evolution of the Internet, multimedia, and communications presents TTI with various opportunities and mediums to implement enhanced deliverables. The team has come up with several methods for enhancing deliverables through the utilization of these technologies. The items described in the list below are just a few examples of deliverable enhancements.

Online reports

TTI's current online report format consisting of a title, abstract, and a few other technical details can be enhanced dramatically, especially given all of the technological innovations that have occurred within the area of web and multimedia technologies. Figure A3 below demonstrates some features that could be added.

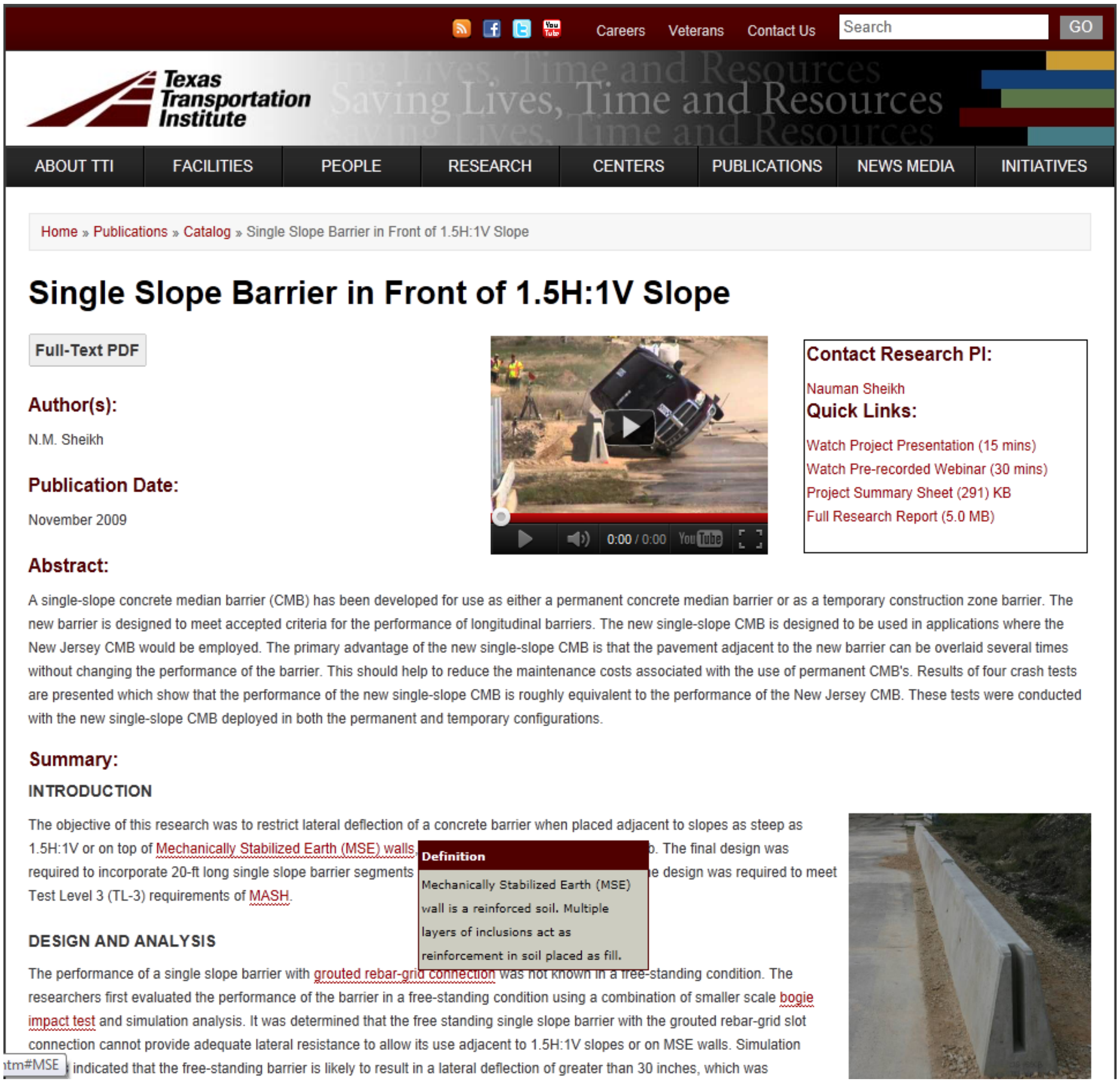


FIGURE A3 Online enhanced features.

Features of this new design include:

- At the top of the page there is an embedded YouTube video that highlights some of the research performed. Embedded videos and multimedia have the ability to provide an engaging overview of the research conducted and reach a broader audience than even an executive summary in a traditional research report could. If a picture is worth a thousand words, how many words is a video worth?

- To the right of the YouTube video is a section for additional information as well as the researchers' contact information. This section can be used for links to items like recorded webinars, PowerPoint presentations, a project summary sheet and even a link to the full research report. By utilizing the power of hyperlinking on the web, relationships between the research project and other relevant information can be instantly accessed.
- Another key element of this design is the use of photos and graphics. While it seems logical to include these, their value should not be ignored. The section below that describes interactive charting provides a detailed example of how advanced web graphics can be utilized.
- One of the most useful features in this new design in our opinion is the ability to hover over keywords within the text and instantly get a definition of what that word means, in the figure above a user has hovered over the Mechanically Stabilized Earth (MSE) walls keyword.

While printed words on page may be ideal in some circumstances, a visually engaging, interactive web page like the example presented here is often better suited for conveying research findings.

Video/multimedia/webinars

While embedding meaningful video on a web page is a viable addition to conveying research results, posting prerecorded videos online is only one method that can be used. TTI also has the ability to stream video of live research as it occurs.

As budget constraints increase for both TTI and the sponsors, there could be an option to provide a method for allowing sponsors witness research as it happens without being physically present. Streaming video of live research results provides a solution that allows sponsors to not only save money on travel but also save productivity time at the office, while receiving continual feedback from TTI throughout the life of a research project. As the ability becomes more prevalent, it perhaps might become as common as video conferencing meetings are today and could provide sponsors with a real savings as compared to other options and/or competitors.

Webinars are another type of video medium that can assist in communicating research findings to sponsors and their customers. These can be as simple as a PowerPoint presentation with the voice of a presenter in the background to full studio quality video of a presentation, similar to presentation of online college courses. Since these can be recorded and played on demand, webinars have the benefit of not requiring project sponsors to be present as the webinar is taking place.

Websites/social media

In today's research markets, an increasing volume of projects are utilizing websites to communicate research findings to sponsors and their customers. These websites are used to improve communication, business processes, and collaboration. For example, there have been several websites developed over the past few years that allow state DOTs to enter information into a central repository to be used as a common reporting mechanism or to assist in partnering on common research projects. The familiarity of the internet to sponsors and their customers will continue to increase, thus driving demand for projects that utilize websites and social media higher and higher.

Mobile applications

The workforce is becoming more mobile as smartphones become more popular. These devices currently have limited features, but as technology moves forward these devices are going to improve in functionality and usability. Three to five years ago, an employee wouldn't have considered going on a business trip without a laptop; however, today employees are utilizing tablet computers similar to the iPad and ultra-small laptops. In the future, these users are going to want this information available wherever they go. The current trend is an increase in the development of websites for projects; however, in the future the trend will be that more and more projects ask for the development of mobile applications.

Interactive charts

Along with websites and mobile applications, sponsors and their customers are going to want information available to them in a much more interactive method. The data-centric nature of many research projects makes any presentation of information critical to the audience's understanding of the research. Many times, the volume of data being represented makes it difficult to interpret the research results. One method of effectively presenting research results is through graphical charts. Charts have historically been used in printed reports or embedded into spreadsheets. The disadvantage of this medium is that charts are static and limited on what they can present. In addition, access to the charts is limited to those who actually have a copy of the research report.

Recently, the internet has evolved into an effective medium for presenting data using interactive charts. The interactive nature of the charts gives users the flexibility of only viewing information that is relevant to them and provides a multi-dimensional window into the information being presented. Providing the charts over the web offers a huge advantage in terms of accessibility and reach. The charts can be developed using free, open source programming libraries that are relatively easy to use. In the examples presented below, the programming library from Google Charts is used. The examples provide several interactive chart samples with a focus on some of types of data that TTI research projects collect. The examples presented here are highly simplified for the sake of clarity but more complex datasets and charts would be relatively simple to integrate.

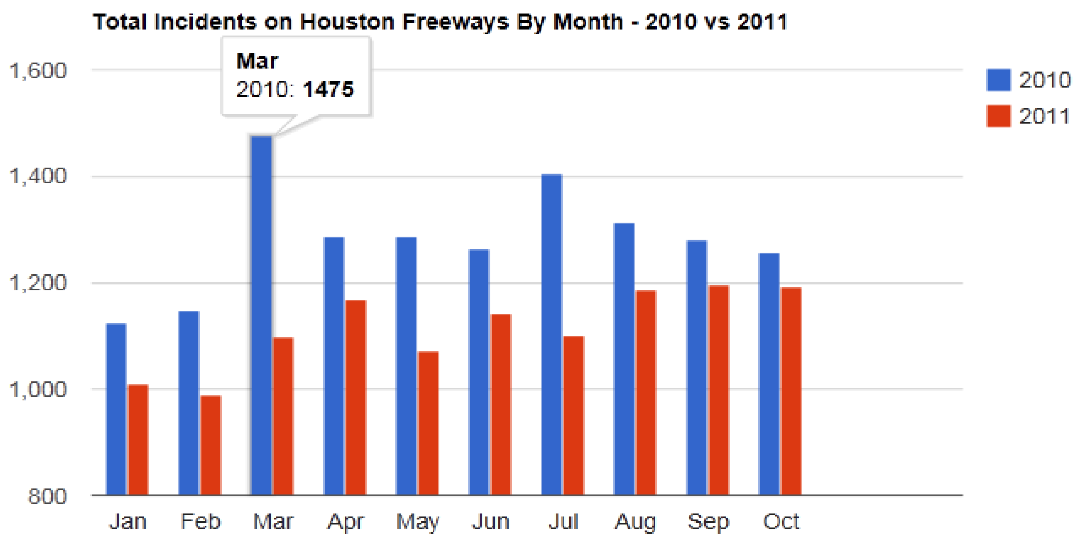


FIGURE A4 Example interactive bar chart.

In Figure 4 above, as the user hovers over different bars the chart provides the underlying information about the data being presented within a call-out box.

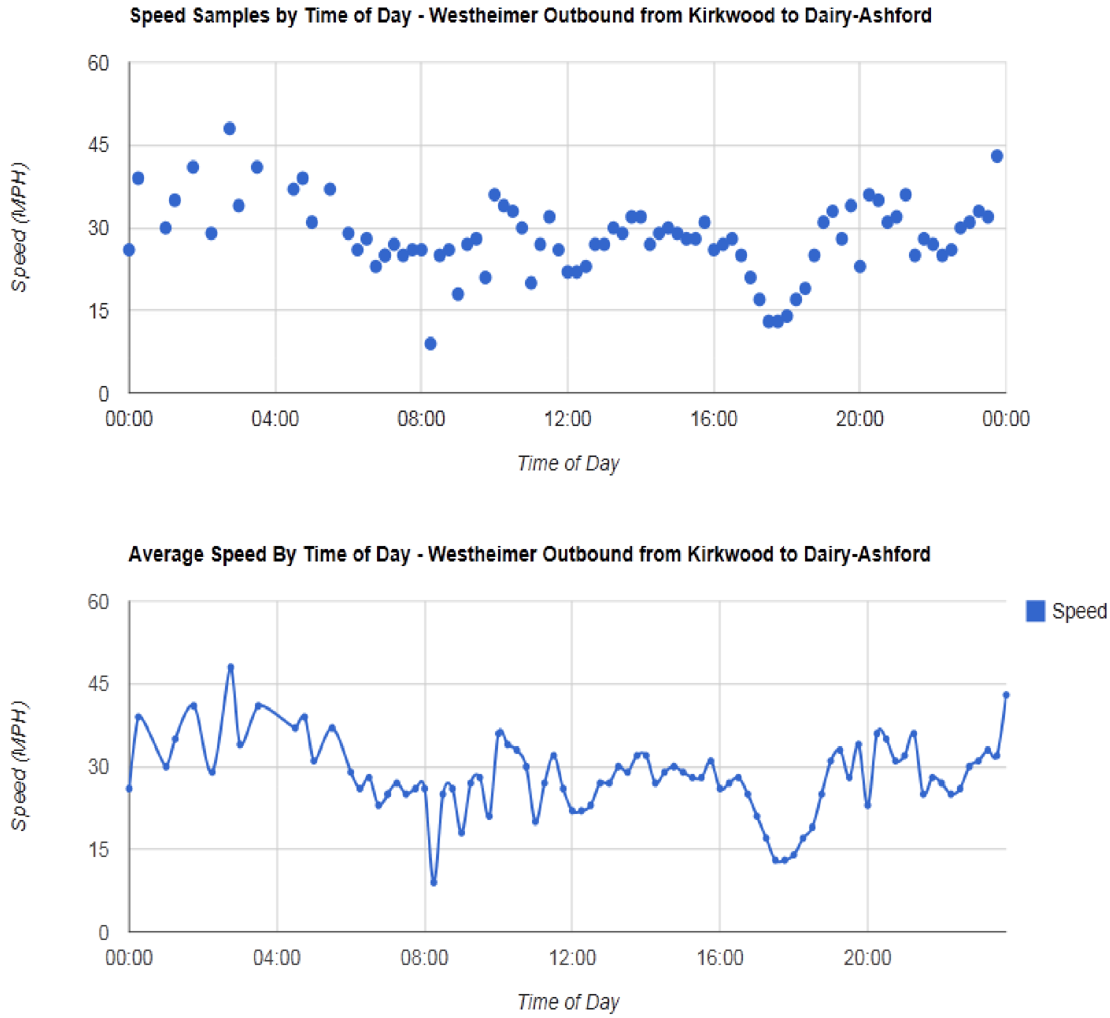


FIGURE A5 Use of external data sources.

In Figure A5 above, the information is pulled from an external data source on a different server. These data sources could include data within databases, spreadsheets, or even web services.

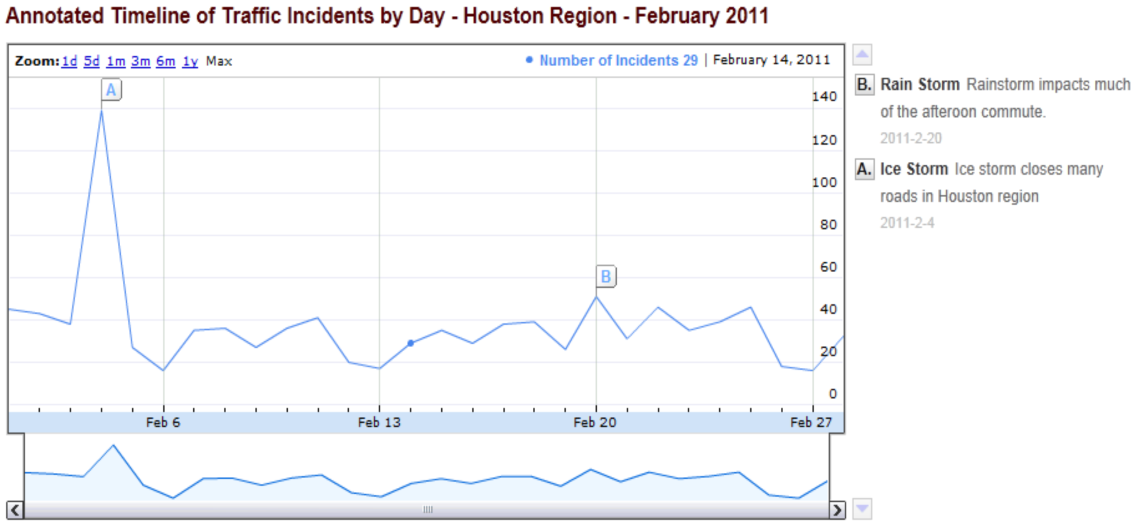


FIGURE A6 Use of chart annotations.

Figure A6 demonstrates the use of annotations of significant events within datasets. In addition, as the user rolls there mouse over various parts of the graph the interactive charts display the raw data across the top of the graph. On the top left of the graph the user also has the ability to zoom the graph in and out to adjust the timeline that is displayed.

Figure A7a and A7b show a comparison as the user adjusts the slider on the commute time data are added or taken away from the chart. Again, as the user rolls over a bar the chart provides the user with additional information.

Some of the benefits of these charts include 1) better accessibility of research results and therefore more visibility by the sponsor, 2) an increased likelihood of the research data to be used as a tool rather than sit on a shelf somewhere, and 3) relative ease of development.

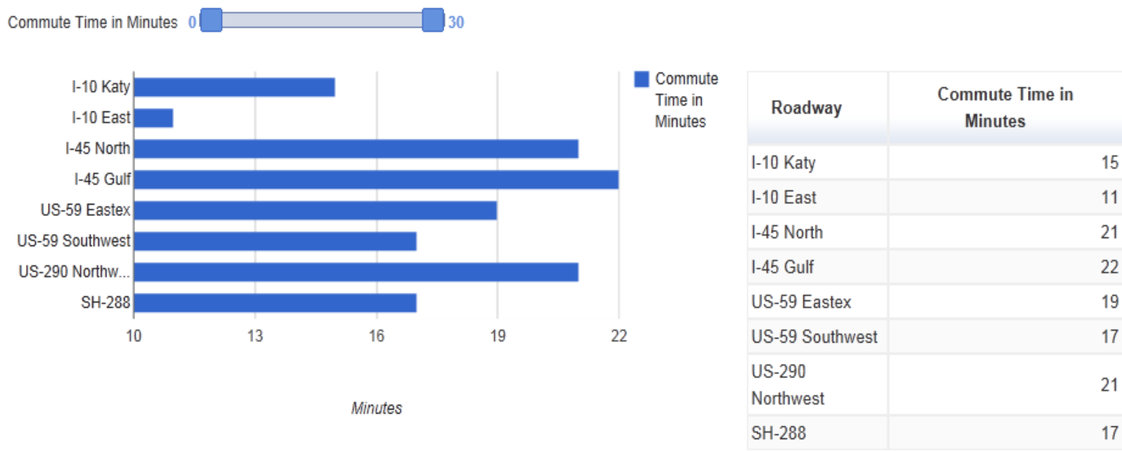


FIGURE A7a User adjustable online information – initial settings.

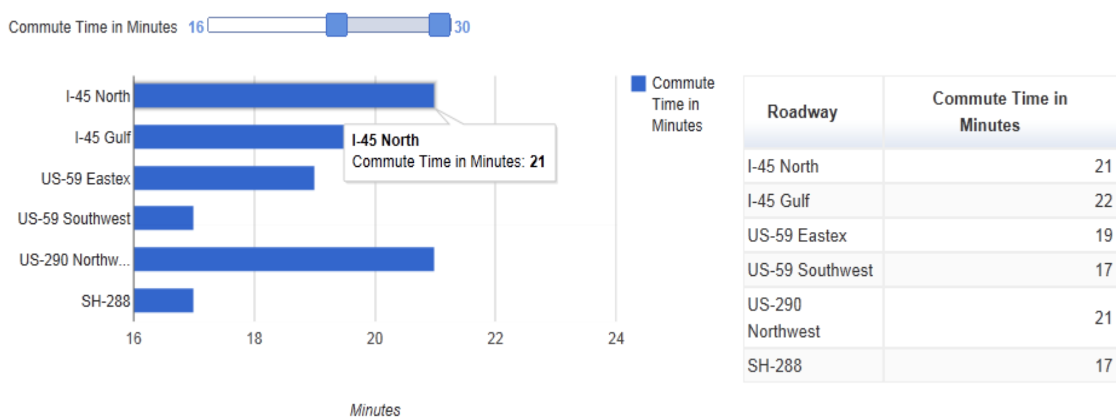


FIGURE A7b User adjustable online information – adjusted settings.

Paper based reports

At first glance a paper based report does not seem like it can be enhanced, but in fact it can be very much improved. TTI has already taken some steps to improve the usefulness of these reports by adding color and doing an executive summary report. Still, these reports can be enhanced even further to include additional graphics and color as well as a short synopsis of the report that summarizes what the research project was set out to figure out, then what was found out and finally how to implement the research.

Deliverable Matrix

As part of the general discussion on the class project, the team members suggested several potential deliverable formats to enhance or replace the current research deliverables. After reviewing the discussion points, the team reached the conclusion that a matrix of deliverables that summarizes and organizes the alternative deliverable formats with regards to the current practice and the deliverable type is needed. The stated purpose of the proposed matrix is to communicate appropriate deliverable choices with researchers and to help TTI and PIs identify and align required resources appropriately.

To develop the matrix, the team looked at differentiating characteristics of deliverables such as research types and deliverable categories. An initial draft of the matrix was developed using the type of research work, e.g., field testing, lab testing, modeling, as the basis for organizing potential deliverable formats. The team reviewed this version and decided that an alternative characterization of the deliverable options might be better suited for the purpose of this task. A second draft of the matrix was developed using the broad type of deliverables as the differentiating factor. After reviewing the second version, the team adopted this version for the task. The matrix was further refined then converted to a web-based table format accessible via internet. Table A3 shows the final version of the proposed matrix. Table A4 accompanies the matrix and provides a summary of identified categories of deliverable options.

The proposed matrix has been developed based on review and suitability of existing technologies and methods that can be implemented with reasonable effort. However, this matrix will need to be reviewed and updated periodically based on new technologies that may become available in the future.

TABLE A3 Matrix of Alternative Deliverable Formats

Type of Deliverable	Current Format	Alternative Format
Software	CD-Rom	Web-Based Interactive Content
		Mobile Application
Equipment	Prototype	Video Clip
	Picture in Report	PowerPoint
		Video Instruction
		Web-Based Interactive Instruction
		Mobile Application
Design Method	Paper Based Description	Web-Based Interactive Content
	PDF Digital Documents	Video Instruction
	CD-Rom	Web-Based Interactive Instruction
Test Procedures	Paper Based Description	Video
		Streaming Video
		PowerPoint
		Video Instruction
		Web-Based Interactive Instruction
		Mobile Application
Analysis, Literature Review, Specification and Best Practice	Paper Based Description	Web-Based Interactive Content
	PDF Digital Documents	
	Pamphlet	
Training Materials	Hard Copy/Binder	Web-Based Interactive Training Modules
	Video Instruction	Webinar (Remote Presentation)

TABLE A4 Summary of Deliverable Format Categories

Broad Category	Sub-Category
Paper Based	Paper Based (Report, Summary Report)
Web-based Content	Multimedia
	Software (Cloud Computing)
	PDF Digital Documents
	HTML Document (Current View)
	Website
	Video (pre-recorded)
	Mobile device optimized HTML Document
	Streaming Video
	Mobile Application
	Interactive Charts
Software	CD/DVD
Prototype Device	N/A
Presentation	PowerPoint
	Webinar (Remote Presentation)
	Video Conferencing

Budgeting

Additional project delivery formats will generate additional expenses that should be considered during project deliverable planning. Expenses will vary according to the deliverable format selected, as some formats are significantly more complex than others. From an expense viewpoint, it is important to select a deliverable format that provides a favorable cost/benefit to TTI and the sponsor. The selected deliverable format should deliver a high level of value at a reasonable cost. Expenses may include additional employee salaries and benefits, contract labor, equipment, supplies, and other expenses, which have to be covered by TTI and/or the sponsor.

Figure A8 is a simplified example of a budget template that can be adapted to fit a variety of deliverable enhancements during the project planning phase. A model like

Texas Transportation Institute
Example Project Deliverable Budget

Project Title
Project Account
Responsible Person
Description
Date

Category	Time (Hrs)	Rate	Amount
Salaries & Wages			
Video - on location	12.00	$ 39.41	$ 472.92
Video - researcher interview	12.00	39.41	472.92
Editor - voice over PowerPoint	10.00	38.63	386.30
Editor - web page	8.00	38.63	309.04
Total Salaries & Wages			$ 1,641.18
Fringe Benefits			
Video - on location		17.20%	$ 81.34
Video - researcher interview		17.20%	81.34
Editor - voice over PowerPoint		17.20%	66.44
Editor - web page		17.20%	53.15
Total Fringe Benefits			$ 282.28
Travel			$ 300.00
Supplies			100.00
Other Expenses			50.00
Total Budgeted Expenses			$ 2,373.46
Funding Sources			
Account XXXXXX			$ 1,000.00
Account XXXXXX			1,373.46
			$ 2,373.46

Notes

FIGURE A8 Enhanced deliverable budget template.

this can be used to outline the additional expenses that will be incurred in the development of the deliverable enhancements and to show the source of funds committed to cover such expenses.

Enhanced deliverables create the potential for many advantages within the TTI research program, including:

However, there are other considerations that must be taken into account when looking at the feasibility of creating and/or requiring enhanced deliverables for projects, as follows:

- Cost/funding implications (TTI investment, pricing structure, and sustainability).
- TTI staff resources and expertise available to produce the deliverable.
- Potential to miss the target or intent of the project.
- One size does not fit all (projects or sponsors).
- ADA/508 compliance.
- Legal issues (safety related projects).
- Evolving process.

Conclusions and Recommendations

The objective of the project was to investigate the need and potential effectiveness for creating enhanced project deliverables to better meet the needs of project sponsors and to enhance TTI's research program. The team looked at the current state of deliverables and interviewed researchers and deliverable users to identify their perceptions of current and enhanced deliverable ideas. Then, the team identified that enhancements in traditional project reporting are needed to maximize benefit of today's audience and to grow the exposure of TTI research.

The team looked at ways current technologies could be used to enhance project deliverables. This information was developed into a matrix of possible enhanced deliverable implementation ideas that outlines different technologies that improve dissemination of information.

The team recommends that TTI form an implementation team to further develop the concept of enhanced project deliverables. The implementation team should include a cross-section of expertise within TTI and oversee the following tasks:

- Develop a pilot program to determine the effectiveness and cost/benefit of enhanced project deliverables.
- Formalize the proposed deliverables matrix to guide researchers in the selection of specific deliverable enhancements.
- Develop a framework for the implementation of specific deliverable enhancements to guide researchers to the resources necessary for the specific product.
- Develop a metric to evaluate the performance of the enhanced project deliverables.