THE UNIVERSITY OF MISSOURI-ROLLA CENTER FOR TRANSPORTATION INFRASTRUCTURE AND SAFETY

UMR National University Transportation Center

STRATEGIC PLAN

University of Missouri-Rolla

July 1, 2006

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MISSION AND GOALS OF NATIONAL UTC PROGRAM

Exhibit I

MISSION: To advance U.S. technology and expertise in the many disciplines comprising transportation through the mechanisms of education research and technology transfer at university-based centers of excellence.

GOALS

1. **Research Selection:** an objective process for selecting and reviewing research that balances multiple objectives of the program.

2. **Research Performance:** an ongoing program of basic and applied research, the products of which are judged by peers or other experts in the field to advance the body of knowledge in transportation.

3. **Education:** a multidisciplinary program of course works and experiential learning that reinforces the transportation theme of the Center.

4. **Human Resources:** an increased number of students, faculty, and staff who are attracted to and substantively involved in the undergraduate, graduate, and professional programs of the Center.

5. **Diversity:** students, faculty, and staff who reflect the growing diversity of the U.S. workforce and are substantively involved in the undergraduate, graduate, and professional programs of the Center.

6. **Technology Transfer:** availability of research results to potential users in a form that can be directly implemented, utilized, or otherwise applied.

STRATEGIC PLAN

Exhibit II

I. PROGRAM OVERVIEW

I.A Glossary

ASCE = American Society of Civil Engineers
CE = Civil Engineering
CIES = Center for Infrastructure Engineering Studies
DOT = Department of Transportation
EE = Electrical Engineering
F&A = Facilities and Administrative
FHWA = Federal Highway Administration
FRP = Fiber Reinforced Polymers
LTAP = Local Technical Assistance Program
MAE = Mechanical and Aerospace Engineering
MEP = Minority Engineering Program
MoDOT = Missouri Department of Transportation
NDT = Non-Destructive Testing
NSF = National Science Foundation
NSTC = National Science and Technology Council
RAB = Research Advisory Board
R&D = Research and Development
STI = Summer Transportation Institute
TRB = Transportation Research Board
UM = University of Missouri System
UMC = University of Missouri-Columbia
UMR = University of Missouri-Rolla
UTC = University Transportation Center

I.B Center Theme

To address national needs in the areas of transportation infrastructure and safety focusing on the following topical areas:

- **Advanced materials** including constructed facilities security, which will involve several tasks:
    - The development, manufacture, and application of modern construction materials.
    - Installation processes and engineering design.
    - Standardization and code approval of products and design protocols.
- **Transition-state fuel vehicle infrastructure** leading to a hydrogen economy, which will require two critical tasks, as follows:

    - Development of safety codes, standards, and regulations.
    - Infrastructure development and deployment.
- **Non-destructive evaluation (NDE) technologies and methods** including monitoring and evaluation of new and repaired structures and system components.

Advanced materials developed for use in the transportation infrastructure offer superior mechanical properties, long-term durability, and design flexibility. Research and development (R&D) in advanced materials address the growing needs for strengthening/rehabilitation of aging structures and for the design/construction of new structures to more stringent requirements and for extended service life. These materials apply to all modes of surface transportation.

Alternative fuel vehicles face the same implementation challenges as that of hydrogen vehicles. Research, development, demonstration, and deployment activities of alternative fuel (including hydrogen) vehicles and supporting infrastructure across all modes of transportation address the growing need for a successful transition to a hydrogen economy.

Recent advances in sensor technologies and NDE techniques offer new methods of non-intrusive, in-situ monitoring of the health, geometric, environmental, and structural characterization of civil structures and their supporting systems. NDE sensor technologies and methods enable more accurate, sensitive, cost-effective, rapid, and straightforward evaluations. Integration of NDE technology to existing and future infrastructure systems will improve network evaluation and enhance the safety of the transportation infrastructure.

The choice of the Center theme comes from an analysis of state and national needs/opportunities, as well as strengths/potential of our institution. We are walking the bridge that connects the transportation infrastructure of the second millennium to that of the third millennium. The existing infrastructure was conceived to support a vehicular traffic powered by fossil fuel and has dramatic shortcomings in terms of durability and congestion. But the future will be an intelligent infrastructure incorporating advances in information technology and supporting a new generation of alternative fuels up to an ending point that is conceivably hydrogen with all the associated challenges in terms of safety, deployment, and market acceptance.

UMR has determined that it is of critical importance to its own mission and future as well as the economical success of the state of Missouri to focus on advanced materials in order to: a) help with the upgrade and maintenance (including security hardening) of the existent infrastructure; and, b) contribute to the development of the new infrastructure. Similarly, NDE methods and techniques are a core area of expertise at UMR and their development and deployment will help society with the health monitoring of the existing infrastructure and will become integral part of the new infrastructure to ensure its acceptance and safety. Finally, the Center will tackle the challenge of alternative fuels (including hydrogen) in a systematic approach as the only viable methodology for the safe deployment of the new form of transportation.

I.C Center Director's Summary

The UMR National University Transportation Center, referred to as the Center henceforth, will provide the means for establishing key relationships with state and federal agencies dealing with transportation as well as industry. With the Center leverage, R&D projects carried out at UMR and elsewhere will establish a national center of excellence in the theme area. The intention is to improve the quality and life span of constructed facilities, provide new NDE and NDT techniques to diagnose constructed facilities, and extend efforts in the transition fuel vehicle infrastructure.

The purpose of the Center is also to impact the quality of engineering education. This purpose is accomplished by developing significant educational resources for training engineers with interdisciplinary skills and experiences and by facilitating the transfer of advanced technology in the theme area. At the conclusion of the Center's life, new academic courses will be in place at UMR for the training of better-prepared engineers.

II. PROGRAM ACTIVITIES

II.A Research Selection

Research Selection Goal: To implement an objective process for selecting and reviewing research that balances multiple objectives of the program.

1. Baseline Measures

See baseline measures 1.1, 1.1a, and 1.2 in Appendix A.

2. Research Selection Program Outcome

The project selection protocol is intended to optimize the use of Center funds for the attainment of its scientific and educational goals. This optimization is accomplished by establishing the areas of funding, proposal format, review process, and reporting obligations. Because matching is required, a research proposal will not be funded by the Center until approval from the co-sponsoring organization is granted. Proposals submitted to MoDOT or other state transportation departments will be given special consideration. The first step in the approval process for UTC match funding is done by the UTC Center consisting of review by the Center Director and Associate Director(s). The prospective proposals are reviewed for appropriateness to the center theme and mission. This review process will normally be done immediately prior to submission of the proposal to the matching agency such that the PI(s) and matching agency are aware if UTC match is available. If the co-sponsoring organization is an agency with an established selection protocol (*e.g.*, proposal format and review process), this proposal approval is also required prior to award of the UTC proposal. Input on the selected UTC projects will also be sought from the Research Advisory Board (RAB).

3. Planned Activities

The Center theme and criteria for project selection are consistent with the 2003–2008 DOT Strategic Plan and the NSTC Transportation and Technology Strategy. In particular, the Center will work towards attaining the strategic goals of mobility and environmental stewardship.

Mobility "*Advance accessible, efficient, intermodal transportation for the movement of people and goods.*" Of this strategic goal, the following outcome goals are relevant to the theme of the Center:

- Improve the structural integrity of the transportation system.
- Balance new physical capacity with the operational efficiency of the nation's transportation infrastructure.
- Provide preventive measures and expeditious response to natural and man-made disasters in partnership with other agencies to ensure that we provide for the rapid recovery of the transportation system.

The first and second outcome goals measure the condition of the physical transportation infrastructure, including the components of the transportation system operated by DOT. Adequate condition is a requisite if transportation is even to take place, especially in a cost-effective manner. The last outcome goal measures accessibility and system recovery in the event of natural and man-made disasters.

Environmental Stewardship *"Promote transportation solutions that enhance communities and protect the natural and built environment."* Of this strategic goal, the outcome goal relevant to the theme of the Center is to reduce pollution and other adverse environmental effects of transportation and transportation facilities.

This outcome goal will examine a transition-state fuel vehicle economy in a new way of doing business that brings together the timely delivery of transportation projects with the protection and enhancement of the environment.

The Center Strategic Plan is also consistent with the Federal Highway Administration (FHWA) 1998 National Strategic Plan. In particular, Center activities will contribute to several goals and objectives within the mobility, productivity, human and natural environment, and national security strategic plan areas including: 1). Preserve and enhance the infrastructure of Federal-aid highways with emphasis on the NHS; 2). Minimize the time needed to return highways to full service following disasters; 3). Improve the return on investment of the highway system; 4.) Improve the quality of the natural environment by reducing highway-related pollution and by protecting and enhancing ecosystems; and 5) Improve the capacity and operation of the highway system to support mobilization.

The Center theme and plan is also consistent with the March 10th, 2006 reported 2006-2010 US Federal Transit Administration (FTA) Strategic Research Plan. In particular, it conforms to Recommendations 4 and 7. Several goals under Committee Recommendation 4 are addressed including UTC projects that will be directed at Goal 2 - Increasing Ridership; Goal 5 - Protect the Environment and Promote Energy Independence. Recommendation 7 - Technology Transition Path through ICE Hybrids to Fuel Cell Buses is also an expected area of contribution for our UTC Center.

4. Required Activities

The Center will solicit research proposals from faculty members at the University of Missouri-Rolla. Proposals will be accepted with provisions on areas of funding, format, review process, and reporting obligations as described below.

Areas of Funding. The Center will consider unsolicited proposals in the areas of advanced materials, transition-state fuel vehicle infrastructure, and NDE technologies and methods with the objective of advancing the state-of-the-art of transportation infrastructure and safety. Three examples of possible areas are listed below:

- Improvement of existing civil engineering construction materials for conventional and extreme events. Among the various construction materials, relatively low cost cementitious materials, reinforced concrete, prestressed concrete, and structural steel are predominant and used to build transportation structures. These materials can be improved to offer better performance, particularly in terms of durability and alternative environmentally sensitive construction materials. New technology in the fields of high performance concrete and steel is of interest to the Center.
- Modeling of composite hydrogen storage cylinders. Pressurized hydrogen storage cylinders are critical components of hydrogen transportation systems (vehicle fuel systems, bulk commodity transport, portable storage, and stationary storage). These cylinders also have pressure/thermal relief devices (P/TRDs) that are activated in case of an emergency. Finite element (FE) analysis is a powerful numerical tool for the design and analysis of advanced engineering systems.
- NDE/sensors. NDE includes monitoring and evaluating new and repaired structures and system components. Smart structures have the ability to sense and perhaps respond to the environment. Good sensing systems possess appropriate sensitivity, discrimination of measurands (the physical quantity being sensed), environmental ruggedness, low cost, distributed capability, and ease of attachment or incorporation with the structure. Fiber optic sensors have a particularly good combination of these desirable properties. Strain, temperature, pressure, and position are some of the measurands sensed and used to assess structural integrity, monitor performance, and perform nondestructive evaluation. The sensor signals may be used to control actuators, which affect the structure. NDT products and implementation processes are of interest to the Center.

Proposal format. A proposal submitted to the Center should present the following:

1. Objectives and scientific or educational significance of the proposed work
2. Suitability of the methods to be employed
3. Qualifications of the investigator
4. Effect of the activity on engineering and education
5. Amount of funding required.

In addition, the proposal should present the merits of the proposed project clearly and should be prepared with care and thoroughness. Sufficient information should be provided in accordance with the Center review criteria identified in the review method description below.

Review method. A Center Research Advisory Board (RAB) [see Section III.C for members of the RAB] Evaluation Process has been established to be used in the selection process for the funding of research projects. The Center director will solicit input from other experts as required to assist in the evaluation process. The merit review criteria for the evaluation of a proposal are listed below.

- Intellectual merit of the proposed activity. How important is the proposed activity to advancing knowledge and understanding within the Center theme? How well qualified is the proposer to conduct the project? To what extent does the proposed activity suggest and

explore creative and original concepts? How well conceived and organized is the proposed activity? Does the proposer have sufficient access to resources?
- Impacts of the proposed activity. How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to transportation agencies and MoDOT in particular?

5. Performance Indicators

Performance indicators for transportation research selection are illustrated in Table A.1 in the Appendix including the starting baseline. These indicators will be collected annually at the end of the current grant year and thereafter.

II.B Research Performance

Research Performance Goal: To implement an ongoing program of basic and applied research, the products of which are judged by peers or other experts in the field to advance the body of knowledge in transportation areas related to the theme of Center.

Reporting obligations. Within 2 months after project completion (i.e. expiration of a grant), the PI is required to submit a final project report. The report will be made available through the Center's website. If the co-sponsoring agency has other reporting requirements, they should also be satisfied, and a copy of the correspondence should be sent to the Center. The PI will also be required to contribute to the required semi-annual reports and newsletter published quarterly by the Center.

1. Baseline Measures

See baseline measures 2.1 and 2.2 in Appendix A.

2. Research Performance Program Outcome

Research projects co-sponsored by the Center will advance the body of knowledge in the following areas:

- Development, understanding, manufacturing, and use of new, more durable construction materials and NDT methods.
- Installation processes and engineering design.
- Monitoring and evaluating new and repaired structures.
- Standardization and code approval of products and design protocols.
- Development and deployment of infrastructure for a hydrogen economy.
- Modeling of high-pressure composite cylinders.
- NDE modalities for hydrogen transportation systems.

- Statistically validated codes and standards for critical hydrogen transportation infrastructure systems.
- Safety of hydrogen-powered vehicles and the infrastructure supporting them.

3. Planned Activities

The Center will interact with state DOTs, public agencies, and three primary industry components (*i.e.*, material and equipment suppliers, general and specialty contractors, and design firms) through the RAB and other means including the Missouri LTAP Center, Missouri Transportation Institute (MTI), and the Center for Infrastructure Engineering Studies (CIES) at UMR. In terms of support, all components are expected to participate, though design firms may provide a smaller financial contribution.

The following types of research activities related to the Center theme are envisioned:

- Development of advanced materials including materials for application to facilities security, both man-made and natural.
- New advanced materials and manufacturing methods.
- Improvement of existing construction materials and methods with emphasis on concrete, steel, and composites.
- Compliance between existing and repair materials with emphasis on interfacial properties.
- New design and construction procedures.
- Development of structural systems and materials for rapid construction.
- Dependable wireless sensor networks for intelligent infrastructures.
- Optimization of electromagnetic acoustic transducers (EMATs) for condition assessment of civil infrastructure.
- Equipment and sensors related to in-situ static and dynamic load testing for assessment and verification of rehabilitation/strengthening procedures.
- Equipment and sensors related to quality control and assurance (Q/C and Q/A) of new construction and repair projects.
- Equipment and sensors related to long-term performance monitoring.
- Protocol for rapid in-situ testing of structural components or assemblies with data interpretation and analysis.
- Engineering of strengthening projects that require composites as the primary structural reinforcement.
- Development of processes for application of structural materials and systems.
- Sensing technology for automated construction processes.
- Real-time structural health monitoring of critical systems.
- Simulations and data visualizations of structural performance.
- Modeling of composite hydrogen storage cylinders using finite element analysis.
- On-site generation of hydrogen from ethanol.
- Statistically validated codes and standards for stationary fuel cells.
- Blast wave modeling involving hydrogen vehicles.
- Hydrogen flammability limits and implications on auto fire safety.

- Statistically validated codes and standards for high voltage disconnect systems in hybrid vehicles.
- NDE of hydrogen transportation systems and sub-systems.
- Test, demonstrate, and validate hydrogen fuel cell vehicles, hydrogen transportation infrastructure, and vehicle and infrastructure interfaces for complete system solutions.

A more detailed description of three possible examples within the topic areas listed above is given in the following fact sheets to serve as representative examples of what a project statement may look like.

- **PROJECT TITLE**: High-performance/high-strength lightweight concrete for bridge girders and decks

OBJECTIVES: The objectives of this research are to 1) develop guide specifications for the use of lightweight concrete in high-strength prestressed concrete girders and in high-performance bridge decks and 2) recommend changes to the AASHTO LRFD Bridge Design and Construction Specifications relevant to high-strength lightweight concrete girders and high-performance lightweight concrete decks.

ABSTRACT: Use of high-strength prestressed concrete girders and high-performance bridge decks has become accepted practice by many state highway agencies because of their technical and economic benefits. These girders and decks are generally manufactured with concrete made with natural, normal-weight aggregates. Use of manufactured lightweight coarse aggregates, such as expanded shale, slate, and clay, to produce lightweight concrete offers the benefit of reducing the weight of the superstructure, leading to reductions in the size of girders, substructure, and foundations. These size and weight reductions facilitate shipping, handling, and construction or replacement of bridge elements and result in economic benefits.

Recent advances in high-performance/high-strength lightweight concrete (HP/HSLWC) have had limited application in bridge construction because of the lack of design and construction guidelines and concerns about material properties and their impact on performance. Research is needed to address the factors that significantly influence the design, constructibility, and performance of high-strength prestressed concrete bridge girders and high-performance bridge decks and recommend changes to the AASHTO LRFD bridge specifications. These modified specifications will provide highway agencies with the information necessary for considering lightweight concrete mixtures that are expected to yield economic benefits.

PROJECT TITLE: Optimization of electromagnetic acoustic transducers (EMATs) for condition assessment of civil infrastructure

OBJECTIVES: The goal of the proposed project is to develop improved sensor designs for magnetostrictive Electromagnetic Acoustic Transducers for the condition assessment of bridges.

ABSTRACT: Concrete is a primary construction material for infrastructure in the United States. The ability to effectively assess the condition of concrete structures during their service life is critically important to maintaining the safety and efficiency of our infrastructure. Corrosion of reinforcing steel bars and strands that are embedded in the concrete is a primary deterioration mode for structures across the spectrum of the civil infrastructure. The Electromagnetic Acoustic Transducer (EMAT) technology to be developed under the proposed project can help address the need for improved condition assessment tools by allowing a

concrete structure to be built with an embedded acoustic sensor network. The embedded sensors will be capable of detecting corrosion, cracking in concrete, and fracture of embedded steel such as reinforcing steel and prestressing strand. This technology will lead to a "smart bridge" that has an embedded sensor network analogous to the nervous system in the human body, detecting deterioration in its embryonic stages such that mitigation methods can be employed. The goal of the proposed project is to develop improved sensor designs for magnetostrictive EMATs that will overcome limitations in the current sensors designs, allowing for the sensors to be embedded in concrete. The improved design and design models to be developed under this project will broaden the scope of application for this unique sensor technology for the condition assessment of bridges and other civil structures.

PROJECT TITLE: Hydrogen infrastructure technologies

OBJECTIVES: The goal of the proposed project is to establish a hydrogen transportation test bed to develop, demonstrate, evaluate, and promote hydrogen-based technologies.

ABSTRACT: UMR in partnership with the Missouri Transportation Institute (MTI) is working on establishing a rural hydrogen transportation test bed and laying the groundwork to develop the "Hydrogen Highway" in the State of Missouri. The demonstration test bed, which includes a hydrogen filling station and hydrogen-powered vehicles, will be crucial to collect and evaluate real-world data, which will help researchers understand the complex interactions between components, system costs, environmental impacts, societal impacts, and system trade-offs. After identifying and analyzing these interactions, researchers can evaluate alternative concepts and pathways, which will result in well-integrated and optimized hydrogen and fuel cell systems. A holistic approach will be taken to address not just the technology but also public perception, permitting, safety standards, and education and training.

4. Performance Indicators

Statistics are obtained from the Center records.

II.C Education

Education Goal: To implement a multidisciplinary program of course work and experiential learning that reinforces the transportation theme of the Center.

1. Baseline Measures

See baseline measures 3.1 and 3.2 in Appendix A.

2. Education Program Outcome

The goal of this education program is to create multidisciplinary educational opportunities for UMR students in the theme of the Center. The specific objectives of the education program are as follows:

- To create a website that will disseminate education related activities that are undertaken and sponsored by the Center.

- To introduce transportation-related career fields to secondary and college students in an effort to bring young talented engineers and scientists into the transportation workforce. This task will be accomplished through summer programs geared towards minorities and females, as well as a Summer Transportation Institute program.
- To provide financial assistance, in the form of scholarships and fellowships, for undergraduate and graduate students who have an interest in studying in transportation related fields. This task includes targeting minority and female students who are not commonly represented in transportation fields.
- To develop ten senior undergraduate/introductory graduate courses related to the theme of the Center, broadening the expertise of students who are studying transportation-related fields at UMR and who will later join the transportation-related workforce.
- To offer graduate–level, transportation infrastructure-related courses live on the internet, so practicing professionals can enhance their technical skills and work towards graduate certificates or graduate degrees.
- To provide technology transfer to the transportation workforce on both a regional and national level through the support of a Local Technical Assistance Program (LTAP) center and through sponsorship of regional and national conferences and workshops.
- To recruit the next generation of educators in transportation-related fields through a faculty enhancement program that will be partially supported by the Center.

The education program has several important features. The content, instruction, and laboratory plans are interdisciplinary with significant teamwork emphasis and reflect the forefront of chemical engineering, electrical and computer engineering, mechanical engineering, structural/material engineering, smart structures, and educational methods. The website will provide immediate interactive access to the educational resources and demonstrations developed during this program.

The education program will address the national need for engineers with interdisciplinary experience and solutions to infrastructure challenges. It is an extension of interdisciplinary research activities at UMR and will involve significant industrial interaction. The industrial interaction will be provided through industry invited lectures and presentations within a classroom setting, opportunities for certification training programs and short courses/conferences outside the classroom, and professional society hosted presentations by industry representatives. Opportunities also exist for undergraduate and graduate student to interface and visit industry representatives through existing undergraduate/graduate research and student-based competitions at UMR. The combination of courses and laboratory learning, Internet access, and educational innovations is a comprehensive approach to disseminating new technology. These many facets will benefit undergraduates, graduate students, their future employers, infrastructure engineering at UMR, other academic programs, and the industry.

3. Planned Activities

The Center director will oversee the educational planned activities. The activities are further described in the following section of the strategic plan.

4. Required Activities

Each year, the UTC will select a Student of the Year. This individual will be awarded a cash prize and full support to attend the award ceremony in Washington, D.C. during the annual winter meeting of the Transportation Research Board (TRB).

Course Descriptions: The program will develop eight senior undergraduate/introductory graduate courses and graduate-level courses offered annually. The courses will be interdisciplinary across the theme areas of the Center. The "Introduction to Structural Dynamics" course will focus on the behavior of structures subjected to extreme events including earthquake and blast. The "Introduction to Traffic Simulation Models" and more advanced "Traffic Modeling and Simulation" courses will focus on the fundamentals of system simulation and development of intelligent transportation systems (ITS) and traffic management. The "Sustainability" course will examine the concepts regarding the continued advancement of humankind including more efficient material and energy use in civil/infrastructure. The "Alternative Energy" course will focus on global energy outlook and available resources with special emphases on renewable energies, transportation fuels, energy efficiencies, and clean technologies. The "Fuel Processing Technology" course will focus on fuel process engineering and analysis of conversion technologies to convert renewable energy sources into fuels. The "Alternative Energy" course will focus on global energy outlook and available resources with special emphases on renewable energies, transportation fuels, energy efficiencies, and clean technologies. The "Fuel Processing Technology" course will focus on fuel process engineering and analysis of conversion technologies to convert renewable energy sources into fuels. The "Hydrogen Technology" course will examine the perspective and motivation for hydrogen energy technologies, advances in renewable energy technologies including hydrogen generation, and storage technologies based on case studies of specific applications; and the "Fuel Cell Technology" course will focus on what materials-based solutions can offer and understanding how the rational design and improvement of chemical and physical properties of these materials can lead to energy alternatives that can compete with existing fuel cell technologies. After the initial offering, where appropriate, these courses will be developed to be offered live over the Internet for distance education students as illustrated in Table II.C.4.

New Course Summary:
Course 1: CE 301 – Introduction to Structural Dynamics
Course 2: CE 301 – Introduction to Traffic Simulation Models
Course 3: CE 301 – Sustainability: Population, Energy, Water, and Materials
Course 4: CE 456 – Traffic Modeling and Simulation
Course 5: AE/ChemE/ME 301 – Alternative Energy
Course 6: AE/ChemE/ME 401 – Fuel Processing Technology
Course 7: AE/ChemE/EE/MSE/ME 301 – Hydrogen Technology
Course 8: AE/ChemE/EE/MSE/ME 401 – Fuel Cell Technology

Table II.C.4. Implementation Schedule of the Main Program Components

	FS 06	WS 07	SS 07	FS 07	WS 08	SS 08	FS 08	WS 09	SS 09	FS 09	WS 10	SS 10	FS 10	WS 11	SS 11
Course 1 - Intro. Struc. Dynamics					O					O DE				O DE	

Course 2 - Intro. Traffic Simulation.				O DE				O DE					O DE		
Course 3 – Sustain.: Pop Energy, Water, Materials.				O					O DE					O DE	
Course 4 – Traffic Modeling & Simu.				O DE				O DE					O DE		
Course 5 – Alternative Energy				O			O DE			O DE			O DE		
Course 6 – Fuel Processing Technology					O			O			O			O	
Course 7 – Hydrogen Technology					O DE			O DE			O DE			O DE	
Course 8 – Fuel Cell Technology							O DE			O DE			O DE		
Curr. Advisory/ Eval. Committee		M			M			M			M			M	

Key: SS = Summer Session; FS = Fall Semester; WS = Winter Semester; O = Offer; DE = Distant-Ed; M = Meet.

Educational Resources: The education program will make extensive use of electronic capabilities and multimedia. The University of Missouri-Rolla website will utilize the latest technology to communicate and provide information to students. In addition, existing senior undergraduate / introductory graduate courses in engineering with sufficient enrollment will be offered live over the Internet for UMR certificate and graduate students through the distance-education program at UMR. These programs include the majority of the 3XX and 4XX courses offered in civil/infrastructure engineering.

Industrial Participants: The RAB (see Section III.C for details) will also serve as a Curriculum Advisory/Evaluation Committee and will meet periodically to evaluate the program. Representation will come from the state, regional, and national levels, including representatives from MoDOT, the Federal Highway Administration (FHWA), and industry including producers, designers, contractors, and educational research community. Other out-of-state DOT representation will also be sought.

Program Evaluation: The program will be evaluated annually by internal review processes and the RAB. The program plans and accomplishments will be examined for balance among engineering disciplines, effective incorporation of laboratory experience and current research, relevance to industry needs, appropriate application of educational methodologies, effective use of multimedia and the Internet, and integration into the current curricula. The internal review will consist of self-evaluation by the faculty and testing and survey of the students. The self evaluation utilized will include the University of Missouri-Rolla internal self evaluation criteria to access if new course development has been successful. This includes monitoring and reviewing the following during the first two offerings: student enrollment requirements, course evaluation by registered students, written course comments by registered students, and instructor evaluation. These criteria will be utilized to ensure quality of course content and instruction prior to University approval as a permanent course.

Program Implementation: The implementation schedule for the program is shown in Table II.C.4. In the fourth year, the new program is envisioned to be fully integrated in the existing UMR undergraduate/graduate curriculum.

Program Dissemination: The University and Center websites will be a resource for the students in the Center theme-related courses, academics in this area at other institutions, professional engineers, and the public in general. For many of the Center theme-related courses, course notes and related items will be available for a more rapid dissemination of the information as compared to a traditional textbook and, consequently, will be emphasized.

The creation of a permanent set of specialized and interdisciplinary courses for UMR students will provide for long-term technology transfer. The experimental courses will be submitted for inclusion in the regular curricula during the third time of offering at the University.

4. Performance Indicators

Statistics were obtained from UMR Admissions Office and the departments that have taught courses and students who have participated in research projects that may be considered transportation/advanced materials/NDE/transition-state fuels related.

II.D Human Resources

Human Resources Goal: To increase the number of students, faculty, and staff who are attracted to and substantially involved in the undergraduate, graduate, and professional programs of the Center.

1. Baseline Measures

See baseline measures 4.1, 4.2, and 4.3 in Appendix A.

2. Human Resources Program Outcome

The primary objective of the Center is to increase public awareness in the importance of constructed facilities and the transportation infrastructure in particular, as they affect the quality of life and functions of society. As a result of this improved understanding and appreciation for the role of the built infrastructure, an increased number of students will be interested in pursuing careers in engineering and related fields.

3. Planned Activities

Undergraduate Students: The Center will actively participate in the ongoing Opportunities for Undergraduate Research Experience (OURE) program at UMR. This program has been established to expand opportunities for a more active form of learning by students, to encourage the interaction of undergraduate students with faculty, to expand the level of research activity on the campus, to help recruit superior students into the graduate program, and to demonstrate that teaching and research are compatible and mutually reinforcing. The Center will encourage and

provide assistance to faculty members willing to supervise undergraduate students as junior colleagues in their research projects, both during the summer session and during the academic year. The Center will also provide financial support through a scholarship program based on merit entitled "Scholarships for Women and Minority Students Studying Engineering and Science." A variety of recruitment and retention programs including the UMR Summer Transportation Institute (STI), the UMR Minority Introduction to Technology and Engineering (MITE) Programs, Women in Science and Engineering (WISE) activities, and other related programs geared to educate and recruit traditionally under represented students in engineering will also be supported. Some of these programs are further discussed in Section II.E.

Graduate Students: The Center will fund research projects that will provide support for graduate students. Availability of stimulating research projects as well as financial assistance should positively affect the number of graduate degrees awarded. The Center will also provide financial support through a graduate fellowship program based on academic and scholarly merit entitled "Graduate Research Training in Transportation Areas." The emphasis of this program will be directed at the recruitment of the most talented Ph.D. students with desire to become future leaders and educators in the transportation field.

4. Performance Indicators

Statistics are obtained from University and Center records.

II.E Diversity

Diversity Goal: To attract students, faculty, and staff who reflect the growing diversity of the US workforce to be substantially involved in the undergraduate, graduate, and professional programs of the Center.

1. Baseline Measures

Due to privacy concerns, RITA no longer requires the collection of performance measurements regarding diversity.

2. Diversity Program Outcome

The primary objective of the Center is to partner with two existing UMR organizations, Minority Engineering Program (MEP) and WISE, to pursue the following goals:

- To enhance the pre-college preparation of minority students, who have potential for careers in engineering with emphasis on civil/transportation infrastructure, and to provide guidance that encourages a greater number of minorities to enter such careers.
- To increase the enrollment of minorities in UMR's engineering and science degree programs by expanding the state and national pre-college talent pool.
- To help minority students achieve B.S. degrees in engineering with emphasis in civil/transportation infrastructure.

3. Planned Activities

The Center will provide assistance to the named UMR organizations by participating in the following activities:

- Pre-college preparation. Engineering Summer Institute, Seven Week Summer Enrichment Program, Project "Lead the Way" in Missouri, and the Summer Transportation Institute for the enhancement of pre-college participation.
- Enrollment. High School Visits, Campus Visitation Program, Scholarship Support, High School Career Fairs, Programs for High School Math and Science, and Teachers Cooperative Community College Transfer Programs for the increase of enrollment.
- Retention. Freshman Orientation, Summer/Co-Op Employment, Academic Advising, and Scholarships.

Among all activities, the Center will devote particular attention to the UMR Engineering Summer Institute. This activity is a one-week summer program designed for minority students who will be high-school juniors and seniors during the following school term. Participants will obtain an understanding of engineering as a profession and will become acquainted with various fields of engineering and with the demands faced by practicing engineers in these fields. The Center will emphasize the infrastructure/transportation-related issues.

4. Performance Indicators

Due to privacy concerns, RITA no longer requires the collection of performance measurements regarding diversity.

II.F Technology Transfer

Technology Transfer Goal: To make available research results to potential users in a form that can be directly implemented, utilized, or otherwise applied.

1. Baseline Measures

See baseline measures 5.1 and 5.2 in Appendix A.

2. Technology Transfer Program Outcome

The technology transfer program will address the need for interdisciplinary experiences and solutions to infrastructure challenges. This program will be an extension of the interdisciplinary research activities of the Center and will involve industrial interaction. The goal of this program is to create multidisciplinary educational opportunities for the greater professional community in the capabilities and use of the center theme areas. The specific objectives of the program are as follows:

- To create a website that features updated results from R&D and links to other websites related to the theme of the Center.

- To develop and offer educational training programs through short courses, workshops, and conferences for professionals.
- To offer more traditional educational opportunities through distance education.

3. Planned Activities

Technology transfer activities will be undertaken through a number of mechanisms. These methods include training courses conducted through LTAP and by UMR. Examples include Superpave asphalt training, concrete QC/QA training, and work zone safety training. Where appropriate, Center-sponsored research projects for the Department of Transportation (DOT) will also include short course/workshop development for DOT personnel such that new design protocols and the latest research outcomes may be immediately implemented by the DOT. Relevant regional and national conferences and workshops will also be supported.

Internet Resources. The Center website will provide immediate interactive access for the greater professional community to the educational resources and demonstrations developed by the Center.

Program Evaluation: The program will be evaluated by the Center Director utilizing an internal review process. Plans and accomplishments will be examined through participant survey for relevance to industry needs, appropriate application of educational methodologies, and effective use of multimedia and the Internet. The internal review will consist of surveying participants. The website will enable users and other browsers to comment, by e-mail, on the website or on the project. Short courses and conferences to the DOT personnel or other professionals will include a survey based evaluation process examining the participants view of strengths and weaknesses of the short course or conference such that improvements can be implemented for future iterations of the short course or conference.

Program Implementation: The implementation schedule for the program is shown in Table II.F.3.

Table II.F.3. Implementation Schedule of the Workshops, Short Courses, and Conferences

	FS-06	WS-07	SS-07	FS-07	WS-08	SS-08	FS-08	WS-09	SS-09	FS-09	WS-10	SS-10	FS-10	WS-11	SS-11
Short Course, Workshop, Conferences	U, L, O	U, L	L	U, L	L	L	U, L	U, L	L	U, L	U, L	L	U, L	U, L	L

Key: WS = Winter Semester; SS = Summer Session; FS = Fall Semester; L = LTAP Training; U = UMR Training; O = Other.

The workshops and short courses will be initially offered to DOT personnel and other practicing professionals. Other opportunities will be pursued through the UMR Distance and Continuing Education Program.

Program Dissemination: Use of the Internet will be implemented as appropriate to disseminate technical information to the professional community at large.

The creation of workshops, short courses, and assisting with specialty conferences for professionals will provide for long-term technology transfer.

4. Performance Indicators

Statistics are obtained from the Center records.

III. MANAGEMENT APPROACH

III.A Institutional Resources

The leading academic departments involved in transportation infrastructure and safety research activities at UMR:

- Chemical and Biological Engineering (CBE)
- Chemistry (Chem)
- Civil, Architectural, and Environmental Engineering (CArEE)
- Computer Science (CSc)
- Electrical and Computer Engineering (ECE)
- Engineering Management and Systems Engineering (EMSE)
- Geological Sciences and Engineering (GSE)
- Material Sciences and Engineering (MSE)
- Mechanical and Aerospace (MAE)
- Mining and Nuclear Engineering (MNE)

A brief list of existing thrust areas and envisioned research activities from the participating academic units (in alphabetical order) is given below. Faculty interests and activities will determine which of these areas will become viable for Center involvement.

- Chemical and Biological Engineering: Energy storage, membrane technology, nanotechnology, and molecular simulation in nanoconfined systems.
- Chemistry: Corrosion, environmental chemistry, polymers and surface coatings.
- Civil, Architectural, and Environmental Engineering: Design methodology development, damage assessment and marginal safety of structural systems, structural strengthening and control, seismic behavior and design of nonstructural components, performance and constitutive modeling of concrete structures, and use of new materials and advanced sensors for intelligent transportation systems, geometric design, traffic, facilities operation, transit and public transport, sub-pavement and pavement materials, soil materials, geotextiles, erosion protection, hazardous waste effects, soil stabilization/improvement, soil structure interaction, soil property measurements, foundations, piping systems, flood control, river engineering, watershed modeling, dams, and flow through porous media.
- Computer Science: Web databases and wireless systems, intelligent systems and data mining.
- Electrical and Computer Engineering: Power electronics and drives, power systems, structural health monitoring, microwave nondestructive evaluation, sensing and telemetering, fiber-optic sensors, and optical engineering.
- Engineering Management and Systems Engineering: Decision support, customer perspectives, management of technology, value analysis, optimization, project management, databases, engineering economics, and logistics systems.
- Geological Sciences and Engineering: Geographical information systems (GIS), risk analysis in geological engineering, and geophysical techniques (*i.e.*, borehole seismics, ground-

penetrating radar, refraction and reflection seismics, gravity and ground-penetrating radar, geologic field mapping, tracer analysis, trench studies, and age-dating).

- Materials Sciences and Engineering: Materials for solid-oxide fuel cells, composites, and mechanical behavior of advanced materials.
- Mechanical and Aerospace Engineering: Computational fluid dynamics, combustion, fracture mechanics, composite materials, finite-element methods, probabilistic/statistical methods, reliability, virtual and augmented reality, transport phenomena, failure and fatigue analysis, smart structures, and design/vibration/control/stability.
- Mining and Nuclear Engineering: Blasting, waterjet cutting, high-level explosives research, and pipeline technology.

A preliminary list of UMR faculty members who have participated in UTC projects as well as expressed an interest in being involved in research projects supported by the National UTC is given. The list is in alphabetical order and includes name, department, and area of expertise:

Anderson, M.D., EE, Electric utility operations, economics, and energy control center design

Anderson, N.L., GG, Seismology and engineering geophysics

Apel, D., MNE, Mining senor technologies

Ayoub, A., CArEE, FEM and NDT applications

Belarbi, A., CArEE, Reinforced concrete

Bham, G., CArEE, Transportation traffic flow

Chandrashekhara, K., MAE, Composites manufacturing and FEA

Chen, G., CArEE, Bridge engineering and seismic retrofit

Cheng, F.Y., CArEE, Structural optimization and seismic behavior

Cheng, M. X., CSc, Ad hoc wireless networking and optimization

Dharani, L.R., MAE, Failure and fatigue analysis

Dogan, F., MSE, Solid oxide fuel cells

Erickson, K. T., ECE, Control systems and systems identification

Ferdowsi, M., ECE, Power electronics, power converters, and electric drives

Flanigan, V., MAE, Composites manufacturing & FEA

Galati, N., CIES, load testing and NDE

Galecki, G., NME, Concrete surfaces/water-jet technology

Ge, L., CArEE, Geotech

Grasman, S., EMSE, Operations and supply chain management, operations research, simulation, and engineering economics

Hagni, R.D., GSE, Aggregate characterization for mineralogy and hardness measurement

Henthorn, K. H., CBE, particle technology for the environment

Isaac, K. M., MAE, Fluid dynamics and combustion, emissions from combustion, and evaporative systems and lean premixed combustion

Koylu, U. O., MAE, Combustion, environmental technology, and formation and emission of pollutants

Krishnamurthy, K., MAE, Alternative transportation fuels

Lee, S., CBE, Supercritical fluid technology, alternative fuels and environmental technology

Liu, X., CSc, Database systems and intelligent systems

Ludlow, D. K., CBE, Catalysts and adsorption

Midha, A., MAE, Design of machinery and pavement testing

Luna, R., CArEE, Geotech-Liquifaction

Maerz, N., GSE, Concrete roughness

Myers, J., CArEE, Bridge engineering and composites used for structural strengthening
Nystrom, H.E., EMSE, Strategic planning
Petry, T.M., CArEE, Characterization and stabilization of expansive clays
Prakash, S., CArEE, Seismic analysis and retrofit of earth retaining structures
Rao, V.S., ECE, Intelligent control, smart structural systems, and structural health monitoring
Raper, J., CBE, Particle technology
Richardson, D.N., CArEE, Construction materials
Schonberg, W., CArEE, Structural impact, dynamics
Sedighsarvestani, S., EE, Sensor networks
Stephenson, R., CArEE, Liquefaction modeling
Sheffield, J.W., MAE, Hydrogen energy, and industrial energy management and waste minimization
Stoffer, J.O., Chem, Material science and polymers
Summers, D.A., ME, Water-jet technology and fluid transporting system
Tien, J.C., MNE, Hydraulics and mineral economics
Wang, J., CArEE, environmental fly ash leaching
Watkins, S.E., EE, Sensors and fiber optics
Wilson, J.W., ME, Mineral ore transportation
Xing, Y., CBE, Synthesis and characterization of manomaterials
Zoughi, R., ECE, Electromagnetics, microwave engineering, and microwave and millimeter wave nondestructive evaluation.

Office and laboratory space is needed to perform the Center-supported activities. Office space is available in the ERL building on the UMR campus to house the administrative staff. The laboratory space for research activities is available in the existing laboratories.

In addition to the academic units, the MEP at UMR promotes and supports increasing ethnic diversity within the university community and increasing the number of minority graduates entering the state and the nation's engineering work force.

III.B Center Director

The Interim Center Director is Dr. John J. Myers, Associate Professor of Civil, Architectural, and Environmental Engineering. He is responsible for all aspects of the Center operation and has primary responsibility for administering the Center awards. The director reports to the Vice Provost for Research at UMR.

The director is responsible for implementing the strategic plan and ensuring compliance with all other UTC Program requirements. The director is accountable for the planning, reviewing, and coordinating projects within the Center. Administrating the budget and recommending all appointments of Center personnel is the responsibility of the director. The director will perform normal administrative duties necessary to the effective operation of the Center.

The director will represent the Center at external meetings and will participate in the annual meetings as scheduled by DOT for all the University Transportation Centers.

III.C Center Research Advisory Board, Faculty and Staff

Center Research Advisory Board. A Center Research Advisory Board (RAB) will be established with the following objectives: to advise the Center director on management and activities of the Center and to contribute to the center direction. Members of RAB will be selected based on personal accomplishments, background, and affiliation on a regional and national level. This RAB is representative of all disciplines and departments covered by the theme of the Center and can effectively guide the Center's course. The RAB composition is shown below:

- R&D Division Representative, MoDOT (Chair)
- State Bridge Engineer, MoDOT
- District Engineer, MoDOT
- Center Director, UMR
- Center Associate Director, UMR
- FHWA Division Bridge Engineer
- Research Structural Engineer (Structures Division), FHWA
- Research Hydrogen Engineer, Industry
- National Level Hydrogen Representative (FTA, RITA or equivalent)
- Bridge Engineer/Fabricator-Producer
- Regional Planning Commission
- Out of State (Non-MoDOT) DOT Representation
- Missouri Transportation Institute (MTI) Representation

Faculty. At present, it is not envisioned that faculty members, other than the Center director, will spend 50 percent or more of their time on Center activities. Two faculty members will actively contribute to the management of the center.

Dr. John Sheffield, Professor at UMR, will serve as the Interim Associate Director. He will assist the Center director in implementing all activities related to the transition-state fuel vehicle infrastructure described in the strategic plan, including the Internet resource.

The Center director and associate director will be responsible for the preparation and submittal of the evaluation portion of the annual report. A key to the Center success will be the effective communication and collaboration among the participants. The Center will continuously record quantitative indicators to assess its management and operation. The assessment will be performed through surveys of the members, faculty, and students to identify those activities and structures that are performing well and should be encouraged, as well as those that are not and should be improved.

Staff. An administrative assistant will serve as a full-time director's assistant. This individual will perform all the administrative and office duties described below.

- Compile, research, and tabulate financial statistics to prepare semi-annual and annual reports.
- Process all salary and wage paperwork.
- Carry out daily office operation/oversee students and staff.

- Receive checks and approve and sign requisitions, vouchers, forms, and documents for director or under own signature.
- Control Center expenditures.
- Oversee hiring of staff.
- Gather, organize, and summarize information requested by director.
- Prepare financial statements monthly/annually for operating units or a department to show profit/loss of grant, contract, fund, or account.
- Select and schedule meeting facilities, equipment, and meals for conferences and meetings.
- Act as assistant to the Center director.

III.D Multiparty Arrangements

There are no plans for multiparty arrangements at this time.

III.E Matching Funds

1. Eligibility

The matching funds for the Center will be a combination of internal and external dollars. No federal funds will be used to satisfy the matching requirement.

Table III.E.1 shows the expected matching funds for the UMR-UTC.

Table III.E.1 Matching funds of existing UMR-UTC

	07/01/06 to 06/30/07	07/01/07 to 06/30/08	07/01/08 to 06/30/09	07/01/09 to 06/30/10	07/01/10 to 06/30/11
MODOT	$440,000	$750,000	$750,000	$750,000	$750,000
INDUSTRY	$793,500	$900,000	$900,000	$900,000	$900,000
UMR/CIES	$72,000	$330,000	$330,000	$330,000	$330,000
NCHRP, Pool Fund, etc.	$229,500	$450,000	$450,000	$450,000	$450,000
OTHER DOT's	$25,000	$300,000	$300,000	$300,000	$300,000
TOTAL	**$1,560,000**	**$2,730,000***	**$2,730,000***	**$2,730,000***	**$2,730,000***

* Rate assumes the same direct operating reduction of 22% as Year 1 of the National UTC.

2. Special Rules

The non-federal share of Center costs may include funds provided to a recipient under section 503, 504(b), or 505 of title 23, United States Code. (Those sections refer to the technology deployment, local technical assistance, and state planning and research programs managed by the FHWA.)

IV. BUDGET DETAILS

The figures listed below are the best estimate of combined federal and matching funds and were taken from the grant agreement and the Center records. These figures are tabulated in Exhibit III.

Total Direct Costs**, $**684,600
Total Other Costs, $533,600
F&A (Indirect) Costs, $341,800
TOTAL COSTS, $3,120,000
Federal funds, $1,560,000
Matching funds, $1,560,000

IV.A Grant Year

The Center grant year coincides with the University fiscal year, July 1 through June 30. Start date of the five-year program is July 1, 2006.

IV.B Salaries

The estimated percentage of time and effort involved in relation to total professional activities for each faculty and staff member is listed in the table below.

Table IV.B Percentage of effort

	UTC % annual salary	**UMR** % annual salary
John J. Myers, Interim Center Director	25	25
John Sheffield, Associate Director	10	10
Administrative Staff Salary	50	50
Other Staff Salary	50	50

The equivalent dollar value of the percentage of effort listed in Table IV.B.1 is shown below with estimates for other staff, research faculty, and students. These figures are tabulated in Exhibit III. It is envisioned that the faculty/students/staff salaries will be for both summer and academic year.

Center Director Salary, $15,300
Associate Director Salary, $10,000
Administrative Staff Salary, $35,800
Other Staff Salary, $35,700
Student Salaries, $231,200
Staff Benefits, $61,100
Total Salaries and Benefits**, $515,500**

IV.C Scholarships

It is a goal of the Center to assist students whenever possible. The scholarship information listed below is one way for the Center to accomplish this objective:

- $1,000 plus travel expenses to Washington, DC for award ceremony at TRB.
- Scholarship efforts extended through MEP, WISE, and UMR-UTC Fellowship programs

IV.D Equipment

It is expected that permanent equipment over $5,000 per unit will be purchased. Total allocated funds for equipment are projected at approximately $67,000.

IV.E Domestic and Foreign Travel

No foreign travel is envisioned at this time, but domestic travel is anticipated throughout the grant year. Travel for Center business is estimated at $7,000 per year for administrative CUTC meetings and advisory panel related travel. An additional $71,400 is allocated to faculty and students for research project related travel and technology transfer efforts.

IV.F Other Direct Costs

The budget includes $253K, which is 50 percent of the participation fee to use two Ford hydrogen internal combustion engine shuttle buses for two years as part of the hydrogen transportation test bed being established to develop, demonstrate, evaluate, and promote hydrogen-based technologies.

IV.G Facilities & Administrative (Indirect) Costs

Facilities and administrative (F&A) costs, referred to as “indirect” or “overhead” costs, are those incurred for common or joint objectives and, therefore, cannot be identified readily and specifically with a particular project or program. The current UMR F&A rate for research is 50.5 percent. Other institutions’ F&A rates may vary slightly.

APPENDIX: BASELINE MEASURES FOR NATIONAL UTC

1. Research Selection

Statistics for this section will be monitored after the end of the first grant year and provided every subsequent year.

Table A.1 Statistics

Transport Research Selection	Base
1.1 Research Projects Awarded by Center	7
1.1a. Number of those projects that you consider to be:	
basic research	2
advanced research	0
applied research	5
1.2 Total Budgeted Costs for Those Projects	*$2,208,800

* Includes Federal and Matching Shares

2. Research Performance

Statistics provided in this section are for Academic Year 2005–06 as a base.

Table A.2 Statistics

Transportation Research Performance	Base
2.1 Number of reports issued that resulted from transportation research projects	16
2.2. Number of transportation research papers presented at academic/professional meetings that resulted from projects	59

3. Education

Undergraduate and Graduate Courses

The following list includes undergraduate and graduate courses presently offered at UMR that are relevant to a transportation infrastructure and safety related curriculum. Courses labeled 200 and 300 are undergraduate level courses, whereas 300 and 400 are graduate level.

Aerospace Engineering

AE 311 Introduction to Composite Materials & Structures [Lect. 3.0] Introduction to fiber-reinforced composite materials and structures with emphasis on analysis and design. Composite micromechanics, lamination theory and failure criteria. Design procedures for structures made of composite materials. An overview of fabrication and experimental characterization. Prerequisite: Bas En 110. (Co-listed with E Mech 381 and Mc Eng 382)

Civil Engineering

CE 211 Transportation Engineering (Lect 2.0 and Lab 1.0) A study of operating characteristics of transportation modes including highways, railways, inland waterways, airways, and pipelines. Consideration of traffic control devices, safety, system capacity, design of routes, planning of urban transportation systems, and economic evaluation of transportation alternatives. Prerequisites: Cv Eng 1, Bas En 50 with a grade of "C" or better.

CE 215 Fundamentals of Geotechnical Engineering (Lect 2.0 and Lab 1.0) Analysis of geotechnical systems including soil classification, index properties, permeability, compressibility and shear strength. Basic geotechnical engineering design principles as they apply to civil constructed facilities, such as analysis of foundations and earth structures. Laboratory determination of the basic properties of soils. Prerequisite: Geo Eng 50 preceded or accompanied by Bas En 110; or Arch Eng 103.

CE 216 Construction Materials, Properties and Testing [Lect 2.0 Lab 1.0] A study of the origin, production, uses and general properties of construction materials accompanied by selected laboratory tests and demonstrations. Prerequisites: Bas Eng 120, Cv Eng 215.

CE 217 Structural Analysis I (Lect 2.0 and Lab 1.0) Loads on Structures. Analysis of statically determinate and indeterminate beams, frames, and trusses. Influence lines and moving loads. Computation of deflections. Development and use of theorems of displacement methods including slope-deflection and moment distribution to analyze statically indeterminate structures. Computer solutions. Prerequisites: Bas En 50, 110 each with a grade of "C" or better. (Co-listed with Arch Eng 217).

CE 221 Structural Design in Metals (Lect 2.0 and Lab 1.0) The analysis and design of structural elements and connections for buildings, bridges and specialized structures utilizing structural metals. Both elastic and plastic designs are considered. Prerequisite: Cv Eng 217 with grade of "C" or better. (Co-listed with Arch Eng 221).

CE 223 Reinforced Concrete Design (Lect 2.0 and Lab 1.0) The analysis and design of reinforced concrete beams, slabs, columns, retaining walls and footings by the elastic and ultimate strength methods, including an introduction to the design of prestressed concrete. Introduction to use of computers as a design aid tool. Prerequisite: Cv Eng 217 with grade of "C" or better. (Co-listed with Arch Eng 223).

CE 229 Foundation Engineering (Lect 3.0) The effect of subsoil conditions on the behavior and choice of foundations. Topics include geotechnical explorations and the design of foundations, which includes the selection of foundation types, the analysis of bearing capacity and settlement of shallow/deep foundations, and retaining walls. Prerequisite: Cv Eng 215.

CE 311 Geometric Design of Highways (Lect 2.0 and Lab 1.0) Development and applications of concepts of geometric design for rural and urban highways. Design controls and criteria; elements of design, including sight distance, horizontal and vertical alignment; cross-section elements; highway types; intersection design elements; types of interchanges and interchange design elements; grade separations and clearance; development of visual elements. Prerequisites: Cv Eng 211 with grade of "C" or better.

CE 312 Bituminous Materials [Lect 2.0 and Lab 1.0] Properties, types, and grades of bituminous materials are presented. Emphasis is placed on usage, distress, surface treatment design, and asphalt concrete mix properties, behavior, design manufacture, and construction. Prerequisites: Preceded or accompanied by Cv Eng 216.

CE 313 Composition and Properties of Concrete [Lect 3.0] Properties of plastic and hardened concrete and the influence of cements, aggregates, water and admixtures upon these properties. The microstructure of cement gel and other factors are related to the behavior of hardened concrete under various types of loading and environments, drying shrinkage, creep and relaxation, fatigue, fracture, and durability. Introduction to statistical quality control of concrete production. Prerequisite: Preceded or accompanied by Cv Eng 216.

CE 314 Geosynthetics in Engineering (Lect 3.0) Geotechnical principles are applied to design of geosynthetic systems for foundation support, earth retention, drainage, and disposal of hazardous conventional wastes. Geosynthetic testing and identification. Emphasis is on design of geosynthetic earth reinforcement, roadway stabilization, filters, and waste containment systems. Prerequisites: Cv Eng 215 with grade of "C" or better.

CE 315 Intermediate Soil Mechanics (Lect 3.0) General principles of soil mechanics and their applications, including mineralogy, soil structure, flow through porous media, shear strength, slope stability and consolidation. Prerequisites: Cv Eng 215 with a grade of "C" or better.

CE 316 Geotechnical Earthquake Engineering (Lect 3.0) Geotechnical earthquake hazards and mitigations, damage to structures, plate tectonics, seismicity, wave propagation, characterization of ground motions, theory of vibrations (1-DOF), effect of local soil conditions on ground response, development of design ground motions, liquefaction, dynamic lateral earth pressures and slope stability/deformation. Prerequisites: Cv Eng 215 with a grade of "C" or better.

CE 317 Pavement Design (Lect 3.0) Structural design of rigid and flexible pavements including loading characteristics, properties of pavement components, stress distribution and the effects of climatic variables on design criteria. Prerequisite: Preceded or accompanied by Cv Eng 216.

CE 318 Smart Materials And Sensors (Lect 2.0 and Lab 1.0) Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics included characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior Standing and Math 204. (Co-listed with Aero Eng, Eng Mech, Mech Eng and Elec Eng 329).

CE 319 Applied Mechanics in Structural Engineering (Lect 3.0) A study of the basic relationships involved in the mechanics of structures. Topics include basic elasticity, failure criteria, fundamental theories of bending and buckling of plates and cylindrical shells for practical application in analysis and design of bridge, building floors, and shell roofs. Prerequisite: Cv Eng 217 with grade of "C" or better. (Co-listed with Arch Eng 319).

CE 320 Structural Analysis II (Lect 3.0) Classical displacement and force methods applied to structures of advanced design. Analysis of indeterminate structures such as continuous beams, arches, cables, and two and three dimensional frames, and trusses. Analysis of indeterminate structures involving temperature and support settlements effects. Prerequisites: Civ Eng 217 or Arch Eng 217. (Co-listed with Arch Eng 320).

CE 326 Advanced Steel Structures Design (Lect 3.0) The design of structural steel systems into a final integrated structure. Plate girders, composite systems, stability, connections, rigid frames, single and multistory buildings, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Cv Eng 221 with a grade of "C" or better. (Co-listed with Arch Eng 326).

CE 327 Advanced Concrete Structures Design (Lect 3.0) The design of structural concrete systems into a final integrated structure. Two-way slabs, long columns, connections, and discontinuity regions, deflections and cracking of beams and slabs, ACI design criteria, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Cv Eng 223 with a grade of "C" or better.

CE 328 Prestressed Concrete Design (Lect 3.0) Behavior of steel and concrete under sustained load. Analysis and design of pre-tensioned and post-tensioned reinforced concrete members and the combining of such members into an integral structure. Prerequisite: Cv Eng 223 with a grade of "C" or better. (Co-listed with Arch Eng 328).

CE 329 Foundation Engineering II (Lect 3.0) Classical earth pressure theories. Analysis of shallow and deep foundations to include bearing capacity and settlement of footings, rafts, piles and drilled piers. Analysis of stability and design of retaining walls and anchored bulkheads. Prerequisite: Cv Eng 229 with a grade of "C" or better. (Co-listed with Arch Eng 329).

CE 341 Professional Aspects of Engineering Practice (Lect 3.0) A study of engineering registration laws, regulations, rules of professional responsibility and standards of practice. Review of causative factors of selected failures and their relationship to professional responsibility. Prerequisite: Senior Standing.

CE 345 Construction Methods (Lect 3.0) Introduction to construction planning, selection of equipment and familiarization with standard methods for horizontal and vertical construction. Application of network analysis and schedules to project control. Prerequisite: Cv Eng 248 with a grade of "C" or better. (Co-listed with Arch Eng 345).

CE 346 Management of Construction Costs (Lect 3.0) Management of construction projects from inception to completion: estimates, role of network preplanning, project monitoring and control. Prerequisite: Cv Eng 248 with a grade of "C" or better. (Co-listed with Arch Eng 346).

CE 349 Engineering and Construction Contract Specifications (Lect 3.0) Legal and business aspects of contracts and contracting procedure in the construction industry to include contracts for engineering services and for construction. Analysis, study of precedents and application of the more important provisions, including charges, differing site conditions, liability, arbitration, termination, disputes, appeal procedure, payment, insurance, inspection, liquidation damages and technical provisions. Prerequisite: Precede or accompanied by Cv Eng 245.

CE 353 Traffic Engineering (Lect 3.0) Driver, vehicle, and roadway characteristics; traffic control devices; traffic studies; intersection capacity, intersection design, traffic safety, and evaluation of traffic improvements. Traffic laws and ordinances, traffic engineering, traffic circulation, parking design, and forecasting traffic impacts. Prerequisite: Cv Eng 211with a grade of "C" or better.

CE 373 Air Transportation (Lect 2.0 and Lab 1.0) Runway configuration, airfield capacity, geometrics and terminal layout and design. Aircraft performance; navigation and air traffic control; airport planning and design; airline operations; aviation systems planning. Prerequisite: Cv Eng 211 with a grade of "C" or better.

CE 374 Infrastructure Strengthening with Composites (Lect 3.0) The course presents composite materials and includes principles of reinforcing and strengthening for flexure, shear, and ductility enhancement in buildings and bridges. It covers the design of exisiting members strengthened with externally bonded laminates and near surface mounted composites. Case studies are discussed. Prerequisites: Cv Eng/Arch Eng 217, Cv Eng/Arch Eng 223. (Co-listed with Arch Eng 374).

CE 375 Low-Rise Building Analysis and Design (Lect 3.0) Fundamentals of structural dynamics including the concept of natural frequency, mode shape, and damping. Responses of single-story buildings under blast, earthquake, and wind loading. Response spectrum analysis of low-rise buildings under earthquake loads. Review of various design loads specified in IBC2000. Design of columns, walls, joints, and frames. Prerequisite: Preceded or accompanied by Cv Eng 221 or Cv Eng 223.

CE 411 Transportation Systems Analysis (Lect 3.0) Concepts and principles fundamental to the planning, design, operation, and management of transportation systems using a systems perspective to transportation problems. Concepts from economics, engineering, operations research, management, psychology, and public policy analysis are used throughout. Topics

include linear and non-linear programming, dynamic programming, supply-demand microeconomic framework, analysis of transportation demand, system performance, network equilibrium, simulation and associated case studies. Prerequisite: Cv Eng 353.

CE 419 Advanced Behavior of Reinforced And Prestressed Concrete (Lect 3.0) Behavior of reinforced and prestressed concrete sections, members and wall/shell-type elements subjected to bending, axial load, shear and torsion. Confinement of concrete. Various truss model theories applicable to main members and struttie model applicable to disturbed regions, joints, and connections. Prerequisite: Cv Eng 223 with grade of "C" or better.

CE 424 Structural Dynamics And Earthquake Engineering (Lect 3.0) Behavior of structural materials, elements, and systems under dynamic loads and earthquake excitation; computer methods for response analysis of lumped, consistent, and distributed mass models; eigen solution techniques; design of 2-D and 3-D seismic resistant structures with current building code.

CE 425 Finite Element Application In Structural Design (Lect 3.0) Concepts of analysis and design. Generalized coordinate models and isoparametric derivations for one, two, and three dimensional elements. Systems with plate and shell elements. Structural instability problems. Elastic and inelastic systems for static and dynamic loads. Studies of computer programs.

CE 453 Transportation Planning (Lect 3.0) Study of urban development, mobility patterns, and the transportation network. Transportation modeling techniques; transportation control plans to improve air quality; consideration of the transportation disadvantaged; transportation planning in small cities and rural areas. Access management and site impact analysis of traffic generators. Prerequisite: Cv Eng 353 or consent of instructor.

Chemical and Biological Engineering

Ch Eng 351: Principles Of Environmental Monitoring (Lect 3.0) This course provides an overview of environmental monitoring methodologies. Discussion covers thermodynamic and kinetic processes that affect chemical transport and fate in the environment. Federal environmental regulations and remediation technologies are also covered with specific examples. Prerequisites: Chem 51, 221, 223, and Physics 23, 24.

Electrical and Computer Engineering

EE 326 Fiber and Integrated Optics (Lect 3.0) Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: El Eng 275 or Physics 321. (Co-listed with Physics 326)

Elec Eng 352: Photovoltaic Systems Engineering (Lect 3.0) Physics and characteristics of photovoltaic (solar) cell technologies, electronic control of alternative energy sources, site selection, array design, energy storage methods, electrical code compliance, stand-alone systems,

grid-intertie systems, legal and economic considerations. Prerequisite: Senior or graduate standing in Science or Engineering.

Engineering Management and Systems Engineering

Eng Mg 314: Management for Engineers (Lect 3.0) The transition of the engineer to manager; planning and organizing technical activities; selecting and managing projects; team building and motivation; techniques of control and communication; time management. Prerequisite: Open only to students who have not taken Emgt 211 or equivalent.

Eng Mg 361: Project Management (Lect 3.0) Organization structure and staffing; motivation, authority and influence; conflict management; project planning; net- work systems; pricing, estimating, and cost control; proposal preparation; project information systems; inter- national project management. Prerequisite: Senior or graduate standing.

Eng Mg 374: Engineering Design Optimization (Lect 3.0) The workshops and short courses will be initially offered to DOT personnel and other practicing professionals. Other opportunities will be pursued through the UMR Distance and Continuing Education Program. This course is an introduction to the theory and practice of optimal design as an element of the engineering design process. The use of optimization as a tool in the various stages of product realization and management of engineering and manufacturing activities is stressed. The course stresses the application of nonlinear programming methods. Prerequisite: Math 204 or 229.

Eng Mg 386: Safety Engineering Management (Lect 3.0) Principles of safety engineering applied to industrial situations; job safety analysis and specifications of solutions; reduction of accident rates, frequency and costs; protective equipment, jugs, fixtures and standards; rules, regulations and law. Prerequisite: Junior standing in engineering or engineering management.

Materials Sciences and Engineering

Mt Eng 350 Composites (Lect 3.0) An introduction to the structure, properties and fabrication of fiber and particulate composites. Prerequisites: Mt Eng 215 & 211 or Cr Eng 102 & 242.

Mechanical and Aerospace Engineering

Mc Eng 312 Finite Element Approximation I - An Introduction (Lect 3.0) Variational statement of a problem. Galerkin Approximation, finite element basis functions and calculations, element assembly, solution of equations, boundary conditions, interpretation of the approximation solution, development of a finite element program, two-dimensional problems. Prerequisite: Math 204. (Co-listed with E Mech 307, Ae Eng 352)

Mc Eng 327 Combustion Processes (Lect 3.0) Application of chemical, thermodynamic, and gas dynamic principles to the combustion of solid, liquid, and gaseous fuels. Includes toichiometry, thermochemistry, reaction mechanism, reaction velocity, temperature levels, and combustion waves. Prerequisite: Mc Eng 221. (Co-listed with Ae Eng 327)

Mc Eng 333 Internal Combustion Engines (Lect 3.0) A course dealing primarily with spark ignition and compression ignition engines. Topics include: thermodynamics, air and fuel metering, emissions and their control, performance, fuels, and matching engine and load. Significant lecture material drawn from current publications. Prerequisite: Mc Eng 221.

Mc Eng 336 Fracture Mechanics (Lect 3.0) Linear elastic and plastic mathematical models for stresses around cracks; concepts of stress intensity; strain energy release rates; correlation of models with experiment; determination of plane stress and plane strain parameters; application to design. Prerequisite: IDE 110. (Co-listed with Eng Mech 336, Aero Eng 336)

Mc Eng 382 Introduction To Composite Materials & Structures (Lect 3.0) Introduction to fiber-reinforced composite materials and structures with emphasis on analysis and design. Composite micromechanics, lamination theory and failure criteria. Design procedures for structures made of composite materials. An overview of fabrication and experimental characterization. Prerequisite: IDE 110. (Co-listed with Eng Mech 381 and Aero Eng 311)

Mc Eng 408 Finite Element Approximation II - Second Course (Lect 3.0) Continuation of Finite Element Approximation I-An Introduction; element selection and interpolation estimates, Lagrange, Hermite, and Isoparametric elements; mixed, hybrid, penalty and boundary elements; eigenvalue and time-dependent problems; threedimensional and nonlinear problems. Prerequisite: E Mech 307 or Mc Eng 312 or Ae Eng 352. (Co-listed with E Mech 408, Ae Eng 408)

Mc Eng 436 Advanced Fracture Mechanics (Lect 3.0) Mathematical theories of equilibrium cracks and brittle fracture, mathematical analysis of elasticplastic fracture mechanics, COD, R-curve and Jintegral analysis. Prerequisite: Ae Eng 336 or E Mech 336 or Mc Eng 336. (Co-listed with E Mech 436)

Mc Eng 484 Analysis Of Laminated Composite Structures (Lect 3.0) An overview of isotropic beams, plates, and shells. Bending, vibration, and buckling of laminated composite beams and plates: exact and approximate solutions. Development of composite shell theory and simplified solutions. Analysis of composite structures including transverse shear deformation and thermal effects. Prerequisite: E Mech 381 or Mc Eng 382 or Ae Eng 311. (Co-listed with E Mech 484 and Ae Eng 484)

Mc Eng 485 Mechanics Of Composite Materials (Lect 3.0) Effective moduli of spherical, cylindrical, and lamellar systems. Micromechanics of fibermatrix interfaces and unidirectional composites. Application of shear leg and other approximate theories to interfaces and composites including fiber pull-out, debonding and matrix cracking. Prerequisite: E Mech 381 or Mc Eng 382 or Ae Eng 311. (Co-listed with E Mech 483 and Ae Eng 485)

Mc Eng 487 Finite Element Approximation III - Nonlinear Problems (Lect 3.0) Formulation of nonlinear problems, iterative methods, solution of nonlinear problems, cover topics of interest to the class. Prerequisite: E Mech 408 or Mc Eng 408 or Ae Eng 408. (Co-listed with E Mech 487 and Ae Eng 487)

Statistics

Statistics provided in this section are for Academic Year 2005–06 as a base.

Table A.3 Statistics

Transportation Education	Undergrad.	Graduate	Total
3.1 Cumulative number of transportation-related courses	43	46	89
3.2 Number of students participating in transportation research projects.	118	29	149

4. Human Resources

Statistics for this section will be monitored after the end of the first grant year and provided every subsequent year.

Table A.4 Statistics

Human Resources	Masters	Doctorate	Total
4.1. Number of transportation-related advanced degree programs	5	5	10
4.2. Number of students enrolled in transportation-related advanced degree programs	13	16	29
4.3 Number of students who received degrees	1	2	3

5. Technology Transfer

Statistics provided in this section are for Academic Year 2005–06 as a base.

Table A.5 Statistics

Transportation Technology Transfer and Outreach	Base
5.1 Number of transportation seminars, symposia, distance learning classes, etc	50
5.2 Number of transportation professionals participating in those events	402

UMR NATIONAL UNIVERSITY TRANSPORTATION CENTER BUDGET PLAN

Exhibit III

Name of Grantee: UMR **Grant Year**: 07/01/06 **through** 06/30/07

CATEGORIES	Budgeted Amount	EXPLANATORY
Center Director Salary	$15,300	
Faculty Salaries	$136,400	
Administrative Staff Salary	$35,800	
Other Staff Salaries	$35,700	
Student Stipends	$231,200	
Staff Benefits	$61,100	30.38% Faculty/Staff
Total Salaries and Benefits	**$515,500**	
Domestic Travel	$78,400	
Foreign Travel	$0	
Expendable Property, Supplies, and Services	$90,700	
Total Direct Costs	**$684,600**	
Scholarships/Tuitions	$213,600	
Subcontractor		
Permanent Equipment	$67,000	
*Other Direct Cost (see Sec. IV.F)	$253,000	
Total Other Costs	**$533,600**	
*Facilities & Administrative (Indirect) Costs	**$341,800**	50.5% F&A
TOTAL COSTS	**$3,120,000**	
Federal Share	$1,560,000	
Matching Share	$1,560,000	

*F&A is computed as 50.5% of total direct, except tuition, scholarships and equipment for UMR.

Other institutions may vary.