

UTAH TRANSPORTATION CENTER 2007-08 ANNUAL REPORT



“INNOVATIVE ENGINEERING AGAINST HAZARDS”



UtahState
University



FROM THE DIRECTOR

KEVIN C. WOMACK, PH.D, P.E.



The second year of the Utah Transportation Center (UTC) as a Tier II University Transportation Center has been one of growth and continued development of very important relationships.

Working with our primary partner, the Utah Department of Transportation (UDOT), the Center received \$350,000 in funding for UDOT critical research this fiscal year. In the future we hope to focus on UDOT's use of accelerated bridge construction (ABC) techniques and assist UDOT in determining the long term performance of bridges constructed using such techniques.

The Center has also maintained our relationship with the Utah Transit Authority (UTA), this year working on a UTA funded project examining the application of LIDAR technology to passenger counting on buses (see page 2). The potential for this technology is extremely high, even to the point of determining when specific passengers both mount and depart from a bus. This type of data would be invaluable to any transit district.

Without a doubt, the highlight of the year was the announcement by the Federal Highway Administration (FHWA) of the contractor for the first five year segment of the Long Term Bridge Performance (LTBP) Program. The FHWA selected a consortium lead by the Center for Advanced Infrastructure and Transportation (CAIT) at Rutgers University with the Utah Transportation Center as the other major university partner within the consortium. The total contract is for \$25 million over five years, the UTC portion will be \$5 million over five years. The beginning of this contract coincides with the start of the new 2008-09 fiscal year for the UTC. Dr. Marvin Halling is the Principal Investigator for the UTC on this project. He, and all his structures colleagues, are excited and ready to go on this monumental project.

For the 2007-08 fiscal year the Utah Transportation Center managed to improve its fiscal performance over its first year as a Tier II Center. For this fiscal year the Center leveraged its Tier II Federal funding 247%, with a total center budget of \$1,417,580. That is an increase of \$278,000 over the previous year (see page 10 for budget details). Continuing to increase this type of leverage means more research projects, technology transfer and graduate student scholarships.

With our new transportation faculty member, Dr. Kevin Heaslip, coming on board in the Fall of 2008, we at the Utah Transportation Center are looking forward to even more growth and excitement in what we do during the next year.

CENTER STAFF

Kevin C. Womack, Ph.D, P.E.
Director
Civil & Environmental Engineering

Marvin W. Halling, Ph.D, P.E.
Associate Director
Civil & Environmental Engineering

Julie H. Duersch
Newsletter Editor

FACULTY COLLEAGUES

Paul J. Barr, Ph.D
Assistant Professor
Civil & Environmental Engineering

James A. Bay, Ph.D
Associate Professor
Civil & Environmental Engineering

Scott E. Budge, Ph.D
Associate Professor
Electrical & Computer Engineering

Joseph A. Caliendo, Ph.D
Associate Professor
Civil & Environmental Engineering

Anthony Chen, Ph.D
Associate Professor
Civil & Environmental Engineering

Kevin P. Heaslip, Ph.D
Assistant Professor
Civil & Environmental Engineering

Robert T. Pack, Ph.D
Associate Professor & Director, Center
for Advanced Imaging Ladar
Civil & Environmental Engineering

Keri L. Ryan, Ph.D
Assistant Professor
Civil & Environmental Engineering

Blake P. Tullis, Ph.D
Assistant Professor
Civil & Environmental Engineering

Chris Winstead, Ph.D
Assistant Professor
Electrical & Computer Engineering

TABLE OF CONTENTS

About the Utah Transportation Center 1

Colleague Highlights & Happenings

Scott E. Budge: New Use for LIDAR Technology Aides Transit
Ridership Tracking..... 2

Robert T. Pack: LIDAR Technology Expands Landslide Research &
Detection..... 3

Blake P. Tullis: What’s Best in Culvert Rehabilitation5

Utah Transportation Center Sponsors Bridge Competition Team6

Student of the Year, Shane D. Boone.....6

2007-08 Utah Transportation Center Projects 7

2007-08 Presentations & Publications 8

2007-08 Facts & Figures 10

Advisory Board..... 11

WEB SITE
<http://transportation.usu.edu>

Cover photo courtesy of Utah Transit Authority

**ANNUAL
REPORT
2007-08**

ABOUT THE UTAH TRANSPORTATION CENTER

The theme for the Utah Transportation Center (UTC) is “Innovative Engineering Against Hazards” and comes from the core expertise of the initial group of colleagues associated with the Center. For the past decade the transportation research expertise within the Department of Civil and Environmental Engineering (CEE) at Utah State University has been in areas addressing natural hazards: earthquakes, landslides, and flooding. It was decided to mold the Center around this expertise and then reach out to other colleagues to provide expertise that can be applied to both hazards and other areas of transportation--congestion and transit being two prime examples.

This approach has been very successful during the first two years of the Center, particularly with the association of colleagues in the Department of Electrical and Computer Engineering (ECE). That association was expanded during the second year with additional colleagues from ECE sharing their wealth of technical and research expertise in the area of transit. We anticipate the expansion of collaboration will continue in the coming years with the addition of colleagues from USU’s College of Natural Resources.

The *educational activities* of the Center continue to be centered primarily around instruction by CEE faculty associated with the Center. These faculty teach an array of transportation-related courses in many disciplines of civil engineering: surveying, structures, hydraulics, operations, transportation design, planning, and engineering economics. Center *research activities* continue to focus on “engineering against hazards,” and have also expanded to include transit. The Center’s principal research partner continues to be the Utah Department of Transportation (UDOT) and has grown to include the Utah Transit Authority (UTA). We anticipate additional partnership with the Federal Highway Administration (FHWA) as well as local agencies in the near future as our work with the Utah Local Technical Assistance (LTAP) Program expands.

The *technology transfer activities* of the Center this past year have been in the presentation of papers at professional conferences--the annual Transportation Research Board meeting being the principal medium for these presentations. Peer reviewed journal publications are also a key element to the Center’s technology transfer activities (see page 8-9 for the list of presentations and publications). With the restructure and reauthorization of the Utah LTAP Center at Utah State University, we anticipate the ability to utilize the Utah LTAP Center for dissemination of Center research results to expand.



The Utah Transportation Center is located on the campus of Utah State University, in Logan, Utah. Since its founding in 1888, Utah State University has evolved from a small, agricultural college to one that is nationally and internationally recognized for its intellectual and technological leadership in land, water, space, and life enhancement.

APPLIED LIDAR AT CORE OF EFFORT TO PROVIDE ACCURATE RIDER COUNTS WITH DR. SCOTT E. BUDGE'S RESEARCH

Dr. Scott E. Budge became interested in electrical engineering quite naturally. His father was an electrical engineer, and as a youth, Scott had fun putting his natural curiosity to work building radios.

Dr. Budge received his degrees from Brigham Young University, and as he prepared to complete his Ph.D., he anticipated joining private industry. Instead, connections with the late head of Utah State University's Electrical Engineering Department, Dr. Richard Harris, served as the catalyst that brought Dr. Budge to Utah State University, and into academia.

When asked about his work with the Utah Transportation Center, Dr. Budge remarked that he finds this particular project to be one that has brought him full circle from his Ph.D. dissertation in pattern recognition. Technology has come a long way in that short time, and it is making the project for the Utah Transit Authority that much more exciting.

"Investigation of the Use of Textel Cameras for Counting Passengers on Public Transportation," is the title of his project, co-funded by the Utah Transportation Center and the Utah Transit Authority (UTA). The purpose of the project is to use the



Dr. Budge and his assistant, John Sallay, set up a demonstration of the LIDAR equipment prototype for use in their transit project.

high accuracy LIDAR technology developed at Utah State University by Dr. Robert Pack (see related article on page 3), to accurately identify individual transit riders as they enter and exit UTA buses.

This isn't something out of "big brother," but instead a way to identify the three-dimensional characteristics unique to each transit rider and allow for accurate transit user counts.

Currently, the methods used for transit counts are limited to less ac-

curate means. For example, you may be able to accurately determine the number of people who enter a bus, but not when specific riders exit (what travel segments they use). Also, the technology currently available to track transit ridership is open for misreading errors that keep counts from being as accurate as desired and needed. The reason behind reduced accuracy to-date has been two-fold: (1) the limited methods available, and (2) the inconvenience to riders. Both of which impact the bottom line for any transit service.



*Just one example of the many transit modes that will be able to utilize the LIDAR-based identification technology being developed at Utah State University by Dr. Budge and his team.
Photo courtesy of the Utah Transit Authority.*

One exciting element of the LIDAR-based method being developed by Dr. Budge and his research team is the ability this will give UTA to accurately determine usage along each segment of a particular transit route. By tracking the three-dimensional characteristics of each rider, they can then compare that data to determine not only the overall quantity of riders but when they

enter and exit the bus. That kind of accurate data would make providing needed service for transit riders more efficient and cost effective.

The beauty of being able to accurately track this kind of data goes beyond daily counts or even segment counting. Indeed, as the data is gathered, they will be able to pro-

vide a long-term picture of transit usage and need allowing for seasonal- and daily-service adjustments depending on the time of day, day of the week, time of the year, or even for special events like conferences, sporting events, or fine arts performances in a given service area.

The ramifications of this technology are astounding when you consider the transit systems in service across the United States and around the world that could benefit from such accurate counting. The dollars saved after the initial investment in this technology are anticipated to be in the millions of dollars. This would help keep transit costs reasonable for riders, while maintaining a high level of service.

Dr. Budge and his team are currently looking for a manufacturer for this technology. This includes both component suppliers and overall manufacture. As the prototypes are tested in UTA buses, the need for mass production will become critical.

TETON DAM FAILURE STILL INSPIRING DR. ROBERT T. PACK IN CURRENT LANDSLIDE RESEARCH

When asked what first interested him in the field of engineering, Dr. Robert T. Pack shared an early experience with engineering failure. As a kid, Dr. Pack's father (who is a civil engineer) took him to see the aftermath of the Teton Dam failure about two weeks after it had happened. Seeing the devastation, and wanting to know more about how to

prevent such disaster, is still a part of Dr. Pack's research interests today!

Dr. Pack took his interest in engineering and received his BS in Engineering Geology from Brigham Young University, followed with an MS in Geological Engineering from the University of British Colum-

bia. After he completed his PhD in Civil Engineering from Utah State University, Dr. Pack has continued his work in both industry (Thurber Consultants, Ltd., Terratech Consulting, Ltd, and Lidar Pacific Corporation) and academia serving as adjunct associate professor and later as a research engineer at Utah State

University's Space Dynamics Laboratory.

Much of Dr. Pack's research has focused around LIDAR (Light Detection and Ranging). At its very basic definition, LIDAR is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. Dr. Pack and his brother Brent Pack, have expanded LIDAR technology as co-inventors of a three-dimensional camera using LIDAR technology.

This multispectral imaging technology is called Lidar ElectroOptic Fusion Sensor or LEFS. It uses a laser system and a color imager to capture 1,000 shots per second, compared to 25 images per second in video. Using hardware and software developed by the Packs, the LEFS system synchronizes the information to build 3-D images (see Herald Journal, "Creating a new image," by Aarin Brunson, February 5, 2004). The new technology is revolutionary because users are now able to produce a 3-D image immediate-



Dr. Robert Pack with the Lidar ElectroOptic Sensor. This is just one part of the tools helping in the landslide research project currently underway on US-89. Photo courtesy of The Herald Journal.

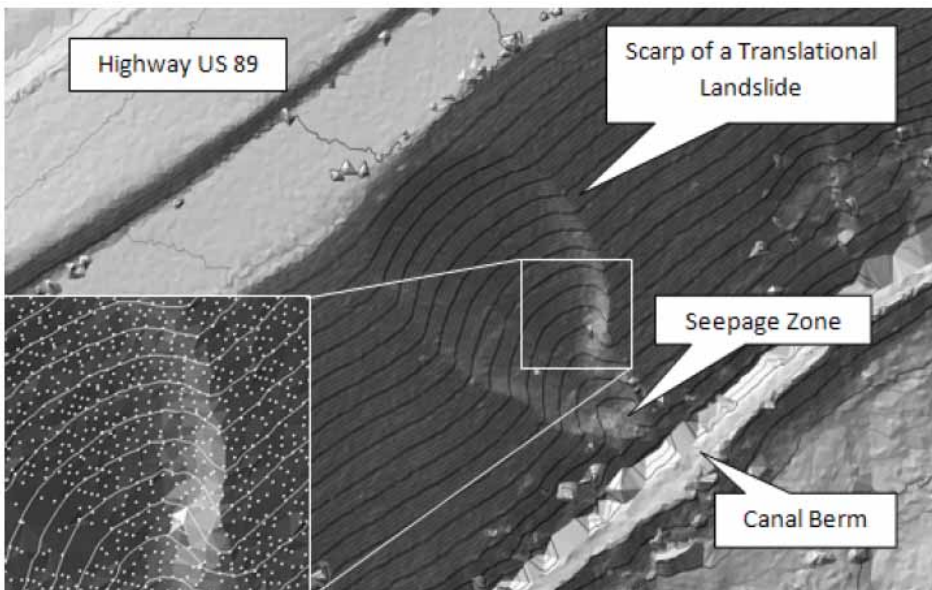
ly, instead of waiting for computers to spend hours transforming the raw data into usable 3-D images.

Dr. Pack has continued fine-tuning, and utilizing this revolutionary technology in his research endeavors at Utah State University, and now with the Utah Transportation Center. He finds applying LIDAR

data to geological engineering problems to be the most fascinating area of his research. And he is doing just that with his current Utah Transportation Center project--Logan Bluff Risk Assessment.

Dr. Pack and his fellow researchers have learned that airborne LIDAR scanning of landslide terrain can discover subtle evidence of potential landslide failure. This is an outstanding development and has been particularly valuable in the Logan Bluff Risk Assessment project, as they help the City of Logan cope with recurring landslide problems below a critical U.S. highway.

This research will benefit not only the City of Logan in managing the critical landslide zone along U.S. Highway 89, but will also add to the resources available for future landslide research and protect our vital infrastructure along such danger zones.



LIDAR survey of landslide surface (shaded 1-foot contour map).

DR. BLAKE P. TULLIS EXAMINES COSTS & BENEFITS OF CULVERT REHABILITATION TECHNIQUES

Dr. Blake P. Tullis is busy doing what he loves...engineering at the Utah Water Research Laboratory at Utah State University. Working with his civil engineer father during the summers got him interested in the field of engineering young, and he's continued that interest into his own professional life.

Dr. Tullis grew up in Cache Valley, Utah and got his BS in Civil & Environmental Engineering from Utah State University. During those undergraduate years, he said he was, "fortunate enough to work at the Utah Water Research Laboratory (UWRL)...and I had hopes of working there again in the future." After he received an MS and Ph.D. in Civil & Environmental Engineering from the University of Michigan and spent a couple of years with a

consulting firm in the Northwest, a position opened up at UWRL and he was hired.

These days Dr. Tullis focuses his research on engineering hydraulic systems. Working with the Utah Transportation Center has been a plus. That partnership has allowed the expansion of the scope of a culvert rehabilitation project initially contracted with the Utah Department of Transportation. The project, titled "Synthesis Study of Culvert Rehabilitation Techniques for Application in Utah," is now underway with UDOT funding, as well as UTC matching funds.

At the core of the project is the fact that old corrugated metal culverts have not been spared as the nation's transportation infrastruc-

ture ages. Utah, along with most states, has a large number of old culverts that have reached the end of their useful life. The bottom (invert) of many metal culvert pipes have rusted away, allowing culvert flow to pass through the road-crossing embankment. Over time, embankment material is washed away and the road can eventually collapse, creating a significant public safety issue.

Dr. Tullis explained that the most interesting thing so far with this project has been seeing up close the ingenuity behind the many different culvert rehabilitation technologies. One example of this ingenuity is PVC pipe that comes flattened in the shape of an I-beam which is then made flexible with steam, dragged through an old culvert, and expanded to line the inside of the old culvert.

Dr. Tullis anticipates that the greatest benefit of this project overall will likely be information provided to UDOT that will allow them to make the most appropriate culvert rehabilitation decisions for individual sites. He continued by saying, "We are also looking for any negative impacts associated with the various culvert rehabilitation techniques or culvert rehabilitation in general (i.e., scour downstream of culverts, culvert fish passage, environmental impacts, etc.). In some cases, culvert replacement may be a better choice."



Dr. Tullis inspects testing equipment at the Utah Water Research Lab

CENTER SPONSORS USU BRIDGE TEAM IN REGIONAL & NATIONAL COMPETITION

The Utah Transportation Center was pleased to help sponsor the Utah State University (USU) AISC/ASCE Steel Bridge Competition team as they attended regional competition at the ASCE Rocky Mountain Region Conference in Golden, Colorado at the Colorado School of the Mines. That win qualified them to advance to the national competition at the University of Florida, in Gainesville in May.

At the national competition, the USU team placed 30th out of the 42 competing teams. The team's best effort was in the Display category, where they placed 17th.

This competition is a great way to provide a realistic steel design experience to civil engineering students, and offers a good deal of fun along the way.



Members of the USU bridge team with faculty member Kevin Heaslip and Department Head Bill Rahmeyer (6th and 7th from left).

“STUDENT OF THE YEAR” HONORS GO TO SHANE D. BOONE



The Utah Transportation Center was pleased to recognize Shane D. Boone as the “Student of the Year” for 2008 (see photo, second from right).

Mr. Boone is from Johnson City, Tennessee and is currently pursuing a Ph.D in Civil Engineering at Utah State University. He performed his undergraduate work and obtained his M.S. in Civil Engineering at The University of Tennessee, Knoxville. His M.S. thesis focused on dynamic testing of a mass concrete fill. During this work he met Utah State University's Dr. James Bay. Dr. Bay's research in stress wave

propagation and seismic testing of soils compelled Mr. Boone to pursue a Ph.D. in these subjects studying under his direction and also under the direction of Drs. Paul Barr, Marv Halling, Kevin Womack, and Thomas Fronk.

Mr. Boone is currently applying stress wave propagation techniques to perform nondestructive testing of concrete structures. He has helped develop a combined stress wave propagation method that incorporates several testing and analysis techniques to determine stiffness profiles and detect voids in concrete tunnel linings and other concrete structures. He is also working on the non-destructive stress and strain measurements of several self-consolidating pre-stressed concrete bridge girders. Also, he has developed an excitation device to detect damage in cyclically loaded concrete specimens.

The goal of Mr. Boone's research is to help develop the understanding of concrete behavior at small strains and to push the envelope of non-destructive testing using stress wave propagation methods. His ultimate goal is to develop instrumentation to be embedded in all concrete structures which would be capable of taking continuous stress wave readings in order to assess instantaneous material properties. Access to instantaneous material property measurements could lead to a variety of applications ranging from simple structural assessments to the development of “smart” structures.

Mr. Boone is employed by the Department of Energy (DOE) in Oak Ridge, TN. After the fulfillment of his Ph.D. he will return there to continue his research in the field of non-destructive testing of concrete and also to work as a lead structural engineer on a variety of projects.

2007-08 UTAH TRANSPORTATION CENTER PROJECTS

PROJECTS RECEIVING UTC FUNDING

New Projects

- UTC0801 “Development of a Decision Support Tool for Assessing Vulnerability of Transportation Networks,” Dr. Anthony Chen, PI. *Co-funded by the Utah Department of Transportation (UDOT).*
- UTC0802 “Synthesis Study and Field Evaluation of In-Situ Culvert Rehabilitation in Utah,” Dr. Blake Tullis, PI. *Co-funded by UDOT.*
- UTC0803 “ABC Deck Connections, Laboratory Testing and Evaluation,” Dr. Marvin Halling, PI. *Co-funded by UDOT.*

Ongoing Projects

- UTC0701 “Evaluation of Bridges for Seismic Retrofit,” Dr. Keri Ryan, PI. *Co-funded by UDOT.*
- UTC0702 “UDOT’s Calibration of AASHTO’s New Prestress Loss Design Equations,” Dr. Paul Barr, PI. *Co-funded by UDOT.*
- UTC0703 “Strong Motion Instrumentation Plan for UDOT Bridges: Array Design, Typical Details, and Specifications,” Dr. Marvin Halling, PI. *Co-funded by UDOT.*
- UTC0704 “Failure Modes Analysis of UDOT’s MSE Wall Inventory,” Dr. James Bay, PI. *Co-funded by UDOT.*

OTHER UTAH TRANSPORTATION CENTER PROJECTS (not receiving UTC funding)

- UTC0804 “Investigation of the Use of Texel Cameras for Counting Passengers on Public Transportation,” Dr. Scott Budge, PI. *Funded by the Utah Transit Authority (UTA).*
- UTC0805 “Shear Capacity of Pre-stressed Girders,” Dr. Paul Barr, PI. *Funded by UDOT.*
- UTC0705 “Logan Bluff Landslide Risk Analysis,” Dr. Robert T. Pack, PI. *Funded by UDOT.*

COMPLETED PROJECTS

- UTC0706 “Wireless Broadband for Commuter Rail: ‘River of RF’,” Dr. Chris Winstead, PI.

2007-08 PRESENTATIONS & PUBLICATIONS

PRESENTATIONS

listed alphabetically by lead author; Utah Transportation Center colleagues in bold

- Boone, S.D., Barr, P.J., Bay, J.A., and Halling, M.W.** (2008). Nondestructive Analysis of a Concrete Tunnel Model Using a Combined Stress Wave Propagation Method, Transportation Research Board, January 2008.
- Boone, S.D., Barr, P.J., Bay, J.A., and Halling, M.W.** (2008). Seismic Wave Measurements in Pre-Stressed Concrete Girders using Embedded Sources and Receivers, Transportation Research Board, January 2008.
- Chen, A.,** Kongsomsaksakul, S., Zhou, Z., Lee, M., and Recker, W. (2007) Assessing network vulnerability of degradable transportation systems: An accessibility-based approach, 17th International Symposium of Transportation and Traffic Theory.
- Chen, A.,** Zhou, Z., Chootinan, P., and Wong, S.C. (2007) Optimizing capacity reliability and travel time reliability in the network design problem, 12th Hong Kong Society of Transportation Studies Conference, Hong Kong, P.R. China.
- Chen, A.,** Zhou, Z., Chootinan, P. and Wong, S.C. (2008) A bi-objective reliable network design model. Paper presented at the 87th annual meeting of the Transportation Research Board, Washington, D.C., USA.
- Chen, A.,** Chootinan, P., and Zhou, Z. (2007) Capacity reliability versus travel time reliability in the network design problem, 3rd International Symposium on Transportation Network Reliability, The Netherlands, July 2007.
- Crookston, B. and **Tullis, B.P.** (2008). "Scour and Riprap Protection in a Bottomless Culvert." Proc., EWRI, ASCE, Reston, Virginia.
- Halling, M.W.,** Hansen, Z.C. (2007). "Structural Monitoring for Bridge Behavior and Damage Detection," Proceedings of 23rd U.S.-Japan Bridge Engineering Workshop, Tsukuba, Japan, November 2007 (invited).
- Halling, M.W.** (2007). "Forced and Ambient Vibration Testing, Monitoring, and Modeling of UDOT Highway Bridges," ASCE Northern Utah Branch, Monthly Meeting, Logan, Utah, December 2007.
- Halling, M.W.** (2008). "Effects of Structural Details on Seismic Behavior: Lessons Learned," Displacement Based Seismic Design of Structures Seminar, Organized by the Vajont Foundation, Longarone, Italy, February 22, 2008.
- Halling, M.W.,** Hansen, Z.C., **Barr, P.J.,** and Marchant, D. (2008). Utilization of Strong Motion Accelerometers for Real Time Monitoring of Structural Properties. ASCE Structures Congress.
- Halling, M.W.,** Xing, S., **Barr, P.J.,** and Hansen, Z.C. (2008). Changes in Modal Frequencies of a Highway Bridge, Sixth National Seismic Conference on Bridges and Highways.

Womack, K.C. (2008). Transforming the U.S. Highway System, National Academies workshop on Critical Needs in the New Technologies: Opportunities for the Technology Innovation Program, April 24, 2008.

Zhu, J.S., Lam, W.H.K., **Chen, A.**, and Lo, H.K. (2008) Modeling the impacts of turn-delay uncertainties on route choice behavior in signalized road networks. Paper presented at the International Workshop on Methodologies for Sustainable Transport, June 5, 2008, Hokkaido, Japan.

PUBLICATIONS

listed alphabetically by lead author; Utah Transportation Center colleagues in bold

Barr, P.J., Yanadori, N., **Halling, M.W.** and **Womack, K.C.** (2007). Live-Load Analysis of a Curved I-Girder Bridge. ASCE Journal of Bridge Engineering, July/August 2007, Vol. 12, No. 4.

Buhler, R., **Pack, R.T.**, Bay, J., Chaiprakaikeow, S. (2008) Logan Bluff landslide slope monitoring program preliminary results. 42nd Annual Symposium on Engineering Geology and Geotechnical Engineering, Boise, Idaho.

Chen, A., Pravinvongvuth, S., Chootinan, P., Lee, M. and Recker, W. (2007) Strategies for selecting additional traffic counts for improving O-D trip table estimation. *Transportmetrica*, 3(3), 191-211.

Chen, A., Yang, C., Kongsomsaksakul, S. and Lee, M. (2007) Network-based accessibility measures for vulnerability analysis of degradable transportation networks. *Network and Spatial Economics*, 7(3), 241-256.

Chen, A., Kim, J., Zhou, Z., and Chootinan, P. (2007) Alpha reliable network design problem. *Transportation Research Record*, 2029, 49-57.

Hsieh, K.H., **Halling, M.W.**, and **Barr, P.J.** (2008). Closure to Overview of Vibrational Health Monitoring with Representative Case Studies. *ASCE Journal of Bridge Engineering*, May/June 2008, Vol. 5, No. 5.

Pack, R.T., Israelsen, P., Petersen, B., Christensen, R., and Crum, G. (2008) Use of USU's new full-waveform airborne lidar in the topographic mapping of a landslide area near Logan, Utah. 42nd Annual Symposium on Engineering Geology and Geotechnical Engineering, Boise, Idaho.

Tullis, B. P. and Robinson, S.C. (2008). "Quantifying Culvert Exit Loss." *J. Irrigation and Drainage*, 134(2), 263-266.

Xu, M., **Chen, A.**, and Gao, Z. (2008) An improved origin-based algorithm for solving the combined distribution and assignment problem. *European Journal of Operational Research*. 188, 354-369.

Zhou, Z. and **Chen, A.** (2008) Comparative analysis of three user equilibrium models under stochastic demand. *Journal of Advanced Transportation* 42(3), 239-263.

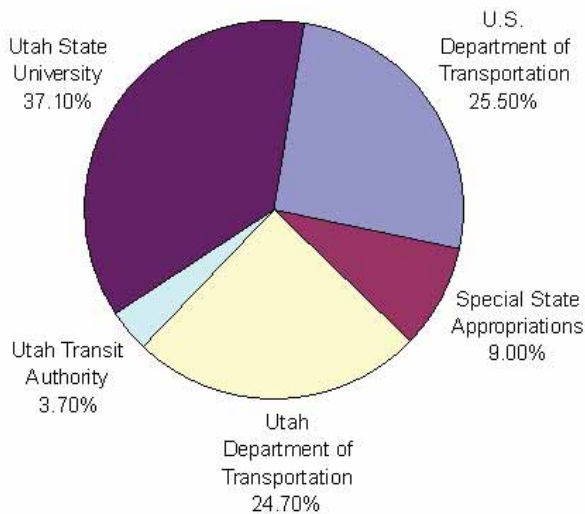
UTAH TRANSPORTATION CENTER PUBLICATIONS

available at the Utah Transportation Center Web site: <http://transportation.usu.edu>

UTC Project UTC0706 Winstead, C., "Wireless Broadband for Commuter Rail: 'River of RF'," 2007.

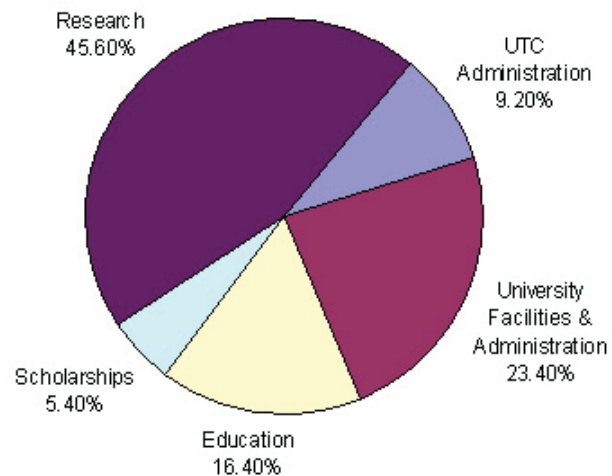
UTAH TRANSPORTATION CENTER FUNDING

Funding by Source



**FUNDING
BY SOURCE**
*Total budget
for FY2008 is
\$1,417,580.00 and
includes funds from all
sources*

Funding by Use



**FUNDING
BY USE**
*includes all funds
expended and
encumbered during
FY2008*

ADVISORY BOARD

Dr. William Rahmeyer, P.E.

Advisory Board Chair and Head, Department of Civil & Environmental Engineering, Utah State University

Bryan Cawley, P.E.

Assistant Division Administrator, Federal Highway Administration

Clair Fiet

Chief Technology Officer, Utah Transit Authority

Ian M. Friedland, P.E.

Technical Director, Bridge & Structures R&D, Federal Highway Administration

Jim McMinimee, P.E.

Director, Project Development Division, Utah Department of Transportation

Benjamin Tang, P.E.

Bridge Preservation Managing Engineer, Oregon Department of Transportation



The Utah Transportation Center is housed in the Civil & Environmental Engineering Department in the College of Engineering, on the campus of Utah State University in Logan, Utah,



Utah Transportation Center
Department of Civil & Environmental Engineering
Utah State University
4110 Old Main Hill
Logan UT 84322-4110