Project Proposal Form

1. Project Team:
   - **Principal Investigator:**
     Name: Chen-Fu Liao  
     Position Title: Research Fellow  
     Organization/University: MTO, University of Minnesota  
     Phone: 612-626-1697  
     E-Mail: cliao@umn.edu

   - **Co-Investigator (if applicable):**
     Name: Max Donath  
     Position Title: Professor  
     Organization/University: Mechanical Engineering, University of Minnesota  
     Phone: 612-625-2304  
     E-Mail: donath@umn.edu

   - **Subcontractor (if applicable): N/A**
     Name:  
     Organization:  
     Project Role:  
     Phone:  
     E-Mail:  

2. Proposal Summary (Abstract) and Objective(s):
   According to work zone injury and fatality data published by FHWA in 2010, there were more than 87,600 crashes in work zones, resulting in 576 deaths and 37,476 injuries. More than 20,000 workers are injured in work zones each year, with 12 percent of those due to traffic incidents [1]. The situation got worse in 2012; 609 out of 33,561 road fatalities were in work zones [2]. Challenges to work zone safety and mobility are also exacerbated by the growing issue of distracted driving.

   This project is one of three components of a work zone safety research proposal to investigate the effectiveness of using in-vehicle messages to calibrate drivers’ understanding of the work zone in order to reduce risky behavior, associated with distraction. This project will examine an inexpensive...
new technology based on Bluetooth Low Energy (BLE) tags that can be deployed in or ahead of work zones. These can trigger spoken and contextual messages in existing smartphones located in vehicles passing by the tag. Such messages can be updated remotely in real time and as such may provide significantly improved situational awareness about dynamic conditions at the work zones such as: awareness of workers on site, changing traffic conditions, or hazards in the environment.

Key technical issues that will need to be addressed are: What is the maximum Bluetooth scanning rate on a smartphone? What is the Bluetooth and data communication latency? What is the power consumption on smartphone and Bluetooth tags? What is the repeatability of Bluetooth communication at high speed? What is the Bluetooth signal attenuation in different environments? How can such a smartphone app be activated requiring no intervention by the driver?

3. Potential Benefits, Users, and Implementation Opportunities:
The key focus of the proposed study is to investigate the feasibility of using inexpensive BLE technology to trigger in-vehicle messages for motorists in work zones. The proposed approach could establish an alternative to automatic speed enforcement to change behavior in work zones by providing dynamic work zone information. The research findings of this project will help to understand the BLE communication performance (latency, scanning rate, power consumption, etc.) in a work zone. The goal is to address potential technical issues of communication between a smartphone and BLE tags at high speed. It is anticipated that this project will provide guidelines for engineers and operational staff to determine the placement of tagged landmarks at work zones for triggering in-vehicle messages.

4. Summary of Research Methodology (Scope):
The latest Bluetooth technology, Bluetooth Low Energy (BLE) or Bluetooth Smart, has considerably reduced power consumption as compared to earlier versions. Low-cost BLE devices have enabled many applications using BLE tags and smartphone devices to locate or identify personal items, or alert owners when personal belongings are left behind. Newer generation of smartphones on the market are now equipped with BLE technology. For example, iBeacon from Apple uses BLE technology to identify locations which trigger an action on the iPhone. According to an article “Mobile Telephony Market”, the Bluetooth Special Interest Group (SIG) predicts that more than 90% of Bluetooth-enabled smartphones will support the low energy standard by 2018.

Commercially available BLE tags are usually configured as non-paired and discoverable Bluetooth devices. A BLE equipped smartphone app (short for “application software”) can continuously scan for BLE devices in the environment. The BLE tag can “broadcast” its service name or other information. When the smartphone app receives the wireless signal from a BLE tag, it will also receive a Received Signal Strength Indicator (RSSI) value with that broadcast message. The RSSI is used to evaluate distance from the tag. Commercially available tags are about the size of a US dollar coin. Some BLE products are even smaller.

A smartphone app will be configured to run as a background service on the phone. This means that the app will be running as soon as the smartphone is turned on. The app can potentially be integrated with 511 or other navigation apps to receive work zone information.

The goal of this project is to address potential technical issues of communication between a smartphone and BLE tags at high speed. However, if the communication range and latency of BLE
cannot meet the technical requirements of the proposed application, we propose to explore a solution using Bluetooth beacons (e.g., Bluetooth class 1 devices) with higher power and longer range of wireless communications.

In order to evaluate the BLE performance, a smartphone and various BLE tags from different manufacturers will be acquired. The research team will develop a data acquisition and testing program on the smartphone to collect BLE ID and signal strength. Multiple test scenarios will be designed to evaluate the communication range, latency, and power consumption under a variety of conditions and when the smartphone user is travelling at different speeds. An in-vehicle app will be developed to demonstrate the system capability and performance under a variety of conditions. BLE performance and experimental findings will be documented in a report.

Connection of this project to the other two components of the work zone safety research proposal
(1) The driver behavior and distraction component will be led by Janet Creaser. This project will identify the problems and assess driver distraction in work zones using crash data analyses as well as through studying objective driver behavior data. This project will design and test dynamic in-vehicle messages that influence the drivers’ understanding of the work zone in order to reduce risky behavior, such as distraction and speeding.

(2) The Traffic Control device tagging and geolocation methodology and application effort will be led by John Hourdos. In this effort, a quick and simple means for BLE Tag/asset deployment and automatic detection will be developed and tested. BLE tags will be located on work zone assets such as signs and barrels. In order to report the deployment of a tagged asset to the central database, the worker that deploys the asset will carry a GPS-enabled smartphone (or tablet) running an app. As soon as he/she walks away from the asset, the app reports it, with its location “dropped” into a cloud-based work zone database. The database capturing the location and tagged asset type can be used to assign a warning message linked to it, which can be dynamically changed as needed from any location.

The following diagram illustrates the relations and components of the work zone safety research proposal.
5. Tasks Descriptions, Durations, Scheduled Dates, and Key Milestones:

Task 1: Acquire BLE Tags and a Smartphone

Description: Purchase a PC, smartphone, data service plan and BLE tags from various manufacturers.

Anticipated Start Date: 7/1/2015
Scheduled Date to submit draft deliverable: 7/30/2015
Scheduled date for final task approval: 8/30/2015
Duration: 1 month
Deliverable: Brief summary report

Task 2: Develop a Smartphone App for BLE Experiments and to “Play” Work Zone Messages

Description: A smartphone app will be developed on a PC to communicate with BLE tags and collect communication parameters. The app when deployed on a smartphone will trigger audio work zone messages (and other modalities as needed) when a tag is detected. We will make sure that our app will run and preempt all other apps that may be running simultaneously, especially 511 and navigation apps. The app will also disable other phone functions while driving through the work zone; all incoming calls arriving while in the work zone will be routed to voicemail and outgoing texts and calls will be restricted (except 911 emergency calls). The content of the messages to be "played" will be determined from the human factors and driver behavior study.

Anticipated Start Date: 8/1/2015
Scheduled Date to submit draft deliverable: 11/30/2015
Scheduled date for final task approval: 12/31/2015
Duration: 4 months
Deliverable: A summary report of the developed smartphone app

Task 3: Experiment Design and Data Collection

Description: This task will consist of experiment design and testing of the app with BLE tags. Research staff will conduct experiments and collect performance data from BLE tags.

Anticipated Start Date: 12/1/2015
Scheduled Date to submit draft deliverable: 3/31/2016
Scheduled date for final task approval: 4/31/2016
Duration: 4 months
Deliverable: A summary report of the experiment results.

Task 4: Data Analysis

Description: This task is to analyze data obtained from the experiments.

Anticipated Start Date: 3/1/2016
Scheduled Date to submit draft deliverable: 5/31/2016
Scheduled date for final task approval: 6/30/2016
Duration: 3 months
Deliverable: Completed data analysis and summary report of results.

Task 5: Compile Report, Technical Advisory Panel Review and Revisions

Description: A draft report will be prepared, following MnDOT publication guidelines, to document project activities, findings and recommendations. The outcome of this report may encourage guideline modifications to the Manual on Uniform Traffic Control Devices (MUTCD) and inform
state legislators about current ASE research findings to apply to the new legislative session. This report will need to be reviewed by the Technical Advisory Panel (TAP), updated by the Principal Investigator to incorporate technical comments, and then approved by Technical Liaison before this task is considered complete. Holding a TAP meeting to discuss the draft report and review comments is strongly encouraged. TAP members may be consulted for clarification or discussion of comments.

**Anticipated Start Date:** 6/1/2016

**Scheduled Date to Submit Draft Report:** 8/31/2016

**Schedule Date for Final Report Approval:** 9/31/2016

**Duration:** 3 months.

**Deliverables:** A draft report and final report approved for publication.

**Task 6: Editorial Review and Publication of Final Report**

**Description:** During this task the Approved Report will be processed by MnDOT’s Contract Editors. The editors will review the document to ensure it meets the publication standard. This task must be completed within the Contract time because the editors will provide editorial comments and request information from the Principal Investigator.

**Scheduled Start Date:** 9/1/2016

**Scheduled End Date:** 10/31/2016

**Duration:** 2 months (required)

**Deliverables:** Final published report.

**Key Milestones:** N/A

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<th>Key Milestones</th>
<th>Target Date</th>
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**6. Budget Details:**

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<th>BUDGET BY LINE ITEM</th>
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<td>PI: Chen-Fu Liao, 29%</td>
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### 7. Budget Justification

The proposed salary budget includes:

- **Chen-Fu Liao (PI):** 4 months of effort (29% effort) for project management, research design, development, data analysis and evaluation over the 16-month project period.
- **Max Donath (Co-PI):** 0.5 months of effort (4% effort) for providing guidance on system design, experimental development and for reviewing results and project report.
- **Researcher:** 6 months effort (50% effort) for programming, assisting experiments, and data analysis over the 12-month period.

Non salary cost includes:

1. Lab supplies: 3,796 total for: PC ($1200 to program smartphone and collect data during the experiment), data analysis software ($200 to purchase software to program BLE tags), BLE tags (20 x $53.8 = $1076), smartphone ($600), data service ($720).
2. Local travel expenses to attend meetings & parking: $220

### 8. Overview of Project Schedule and Budget:

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### 9. Fiscal Year Funding Split:

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1. It takes roughly 10 to 12 weeks for a work plan to be processed. Please allow three months from the date of the pre-contract TAP meeting before your desired start date for contract processing.

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10. Budget Justification
See 7.

11. Administrative Requirements:
A work order will be issued under the terms and conditions of the Master Contract between the State of Minnesota and the University. The proposal submitted to MnDOT must comply with the terms and conditions of the Master Contract. It is understood that PIs, through the University Authorized Representative for the Master Contract, are aware of the Master Contract requirements for budgeting, quarterly progress reporting, final deliverables, invoicing, reimbursement of travel expenses and payments. A copy of the Master Contract can be obtained from your Office of the Sponsored Projects or Program Administration or from your contracting office.

For the Minnesota State College and University System – a work order will be issued under the terms and conditions of the Interagency Agreement between MnDOT and the University.

In addition, it is expected that the PIs will make themselves available to meet with MnDOT Research Services staff, if necessary, to formally review the project progress on semi-annual basis. In most cases this will occur if the project falls behind schedule. PIs shall prepare necessary documentation and information to facilitate meaningful project reviews.

12. Matching Funds, In-Kind or other Contributions:

13. Intellectual Property/Trade Secret Information:

14. Agency Assistance (MnDOT or other):

15. **Resumes for PI and co-investigator(s):**
   - Website Link(s): ________________________ Or  Resume uploaded to CTS resume website

16. **Literature Search and Summary of Relevant Previous Work:**
Bluetooth technology has been used in recent years as an inexpensive and reliable way to collect travel time information on roadways [3]. Anonymous travel time monitoring is performed by matching the Media Access Control (MAC) addresses of Bluetooth devices embedded on cell phones or GPS navigation devices. Bluetooth technology does not require line of sight, however its signal attenuation may be influenced by physical obstacles. The Bluetooth travel time monitoring system produces a matching rate in 1% to 6% range [4, 5 & 6].

Liao [7] recently developed a support system using smartphone and Bluetooth technologies to help people with vision impairment navigate in or around a work zone. A smartphone app based on the Android operation system was developed for providing audible messages to people with vision

<table>
<thead>
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<th>Fiscal Year</th>
<th>Timeframe</th>
<th>List tasks according to scheduled completion dates</th>
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<tr>
<td>TOTAL</td>
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Impairment at a work zone. Global positioning system (GPS), Bluetooth technology, text to speech (TTS) interface, and digital compass already equipped on a smartphone were integrated with a digital map in the smartphone app. The smartphone app will communicate Bluetooth beacons installed near a work zone to help determine a user’s location and provide corresponding navigational guidance instructions.

Bluetooth beacons were programmed to operate in discovery mode with minimal power consumption. The navigation program runs continuously in the background as a service on the smartphone. The smartphone app will continuously scan for Bluetooth devices in the vicinity and identify available information related to work zone and/or signalized intersection by comparing the identification (ID) of detected Bluetooth beacons with a spatial database.

Functionality testing and system validation of the smartphone app were performed by attaching 4 Bluetooth beacons to light posts near a construction site in St. Paul, MN. A research student carried the smartphone with the app and walked around the test sites repeatedly from different directions to validate the audible messages, Bluetooth communication and other user interface. The validation result confirms that the smartphone vibrated for about one second and announced the corresponding audible message to the traveler as a user was walking toward a Bluetooth beacon.

The latest Bluetooth technology, Bluetooth Low Energy (BLE) or Bluetooth Smart, has considerably reduced power consumption as compared to earlier versions. Low-cost BLE devices have enabled many applications using BLE tags and smartphone devices to locate or identify personal items, or alert owners when personal belongings are left behind. Newer generation of smartphones on the market are now equipped with BLE technology. For example, iBeacon from Apple uses BLE technology to identify locations which trigger an action on the iPhone. According to an article “Mobile Telephony Market”, the Bluetooth Special Interest Group (SIG) predicts that more than 90% of Bluetooth-enabled smartphones will support the low energy standard by 2018.

17. References:

**Required for proposals submitted during annual solicitation only.**