Navigating work zones can be challenging for all pedestrians. However, it’s especially difficult for people who are blind or visually impaired. Due to differences in spatial perception as compared to sighted travelers, people with vision impairment usually encounter physical or information barriers that limit their transportation accessibility and mobility. Individuals with vision impairment often face additional challenges while navigating around work zones or crossing intersections due to insufficient information that is available to them.

To help visually impaired pedestrians find their way safely, University of Minnesota researchers have developed a smartphone app together with embedded sensors on the smartphone and Bluetooth technology to detect upcoming work zones and provide routing instructions to pedestrians.

What’s currently there
The Manual on Uniform Traffic Control Devices (MUTCD) published by the FHWA and the Minnesota MUTCD provide specific guidelines for temporary traffic control (TTC) in work zones and outline specific requirements to accommodate pedestrians with disabilities. One of the requirements is to provide audible information for the visually impaired. Audible messages for a temporary pedestrian route shall include a complete physical description of the temporary pedestrian route including duration, length of and distance to the bypass, any restrictions or hazards, and project information.

Currently, a few pedestrian audible devices with push-button and motion-activated options are commercially available for temporary pedestrian traffic management in work zones. These audible devices are usually placed at a distance prior to a construction site. As the pedestrian approaches, he/she hears a unique locator tone, which indicates audible information is available. By pushing the button on the device, audible messages will then be announced to pedestrians. The locator tone can be programmed to play continuously or it also can be activated by motion sensors.

Some concerns of these audible systems are: (1) a pedestrian needs to locate and push the button to hear the messages; (2) when
the messages are automatically activated by motion sensors, pedestrians often are not sure if the messages are relevant to them as they walk by; and (3) consistency of information elements in a pre-recorded message and its clarity and volume in an outdoor environment may be hard to understand or remember.

Information overload could be another concern as most people may have difficulties in memorizing long verbal messages accurately. Transportation engineers and practitioners often face challenges between verbosity and efficiency of auditory messages. Managing the audible devices and ensuring accurate messages are displayed at the correct location could present additional challenges due to the dynamic nature of a construction site.

Guided by beacons

A smartphone-based approach was proposed to present audible messages to visually impaired pedestrians as they approach work zones. For work-zone detection, Bluetooth beacons are mounted to barricades, light posts or installed inside traffic cones at decision points. Bluetooth beacons are programmed to operate in discovery and non-pairing mode with minimal power consumption. A smartphone app was developed to detect upcoming work zones and provide corresponding audible messages to alert pedestrians in the vicinity. The app runs continuously in the background as a service on the smartphone, scanning for Bluetooth devices within the range of communication and identifying available information related to work zones.

When a work-zone Bluetooth beacon is detected, the smartphone vibrates for 1 second to alert the user, and the app will then announce the corresponding messages associated with the detected beacon. In case pedestrians did not hear the complete messages from the phone, they can perform a single tap on the smartphone screen, as many times as needed, to repeat the messages.

The best information

A survey was conducted prior to system design in order to identify types of information that might be best for navigation around work zones. The survey was designed to assess the views of the visually impaired individuals on four different audible messages with different level-of-information details.

Survey results were analyzed to develop guidelines in determining various message elements that are essential and useful for providing routing or bypassing work-zone instructions to the visually impaired. Based on the results, the research team recommended the following four audible message elements that are essential to providing work-zone information to pedestrians with vision impairment:

1. Brief announcement to get pedestrian’s attention;
2. Current location of a pedestrian;
3. What and/or where (such as accessible path availability and construction duration); and
4. Advisory action.

A sample audible message presented to users near a work zone is described as, “Attention southbound Lyndale Avenue pedestrians. You are at southwest corner of Lyndale and Franklin. West sidewalk closed from 22nd to 26th Street for four blocks. Cross Lyndale and use sidewalk on the other side.” Testing of the usefulness of the content and structure of “ideal messages” as determined by the survey would then later be tested in the real world to determine how well the messages and the app worked.

Receiving a message

The work-zone navigation system consists of three key components: (1) a digital map database for spatial reference, (2) a smartphone app and (3) Bluetooth beacons. User input on the smartphone is implemented by performing a single-tap on the smartphone screen for repeating audible messages. Vibration and audible feedback are used to provide information to users when a Bluetooth beacon is detected and identified.

Geometry information of a work-zone area, such as location (latitude, longitude) of Bluetooth devices, and associated advisory messages can be programmed and uploaded to the spatial database through another smartphone app (see Figure 1) used by a work-zone engineer. The work-zone database app allows engineers to deploy and update accessible audible messages around a work zone quickly and easily.

The smartphone app keeps a local digital map containing messages of Bluetooth beacons within a 10-mile by 10-mile area from a user’s current GPS location. The local copy of the digital map is updated automatically as users travel outside the 10-mile region. In order to receive the latest work-zone information updates, the smartphone app also checks for map updates from the central database server every 10 minutes.

When a pedestrian is approaching a work zone and a detected Bluetooth beacon is identified, the smartphone will vibrate for 1 second to alert the pedestrian. The app will then announce corresponding audible messages associated with that detected Bluetooth beacon through the Text to Speech (TTS) interface on the smartphone. After the message is announced, users can repeat the message or follow the advisory action to the next decision point where another Bluetooth beacon will provide additional message updates to guide them through or around work zones.

GPS on a smartphone provides a relatively accurate user location in an open space. However, in urban canyons or indoor environments, the position solution is unavailable or degraded due to signal strength, reflections and multipath. The purpose of using low-power Bluetooth devices is to identify a pedestrian’s location more accurately and reliably, such as at a corner of a street. The antenna range

Figure 1. Work-zone-database app.
of Bluetooth beacons used in this project is typically from 75 to 150 meters. The Bluetooth devices were configured to reduce maximum antenna power to cover a smaller area, for example, a 5- to 10-meter radius. Smart Bluetooth modules can be placed at intersection corners or key decision points near work zones to provide more accurate position and guidance information. As illustrated in Figure 2, corresponding audible messages can provide appropriate routing information to visually impaired travelers by following the red dash line. A geo-fence zone is a predefined set of boundaries that describe a virtual perimeter for a real-world geographic area.

**A true navigation system**

Functionality testing of the smartphone app was performed by attaching four Bluetooth beacons to light posts near a construction site in St. Paul, Minn., as illustrated in Figure 3. A pedestrian carried the smartphone with the app and walked around the test sites repeatedly from different directions to validate the audible messages, Bluetooth communication, detection and other user interface. The validation result confirmed that the smartphone vibrated for about 1 second and announced the corresponding audible message to the user as they approached a Bluetooth beacon located about 15 ft away.

Additional research will be conducted with visually impaired users to evaluate system reliability and usefulness. An implementation study is essential and needs to be robust in terms of numbers of participants and needs to be completed at different work zones with different configurations (same side of street route and a route that requires crossing the street, simple and more complex). Data should be recorded and analyzed in terms of travel time, number of correct/incorrect responses/movements, understanding, safety, and user confidence.

The research team previously developed a smartphone app to provide geometry and
signal timing for the visually impaired at signalized intersections. The intersection crossing and work-zone navigation apps will be integrated as one smartphone-based navigation system for assisting the visually impaired approaching work zones and signalized intersections.

There are opportunities to include many other applications for blind users using this approach to provide information access. It is an easy way to provide location-specific information and directions. For example, the smartphone app can incorporate additional functions to help identify the location of a bus stop and provide bus-arrival information to people who are blind or visually impaired. R&B

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For more information about this topic, check out the Safety Channel at www.roadsbridges.com.

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