Mobile User Interface Development for the Virginia Connected Corridors

CVI UTC

CONNECTED VEHICLE/INFRASTRUCTURE UNIVERSITY TRANSPORTATION CENTER (CVI-UTC)

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Connected Vehicle/Infrastructure UTC

The mission statement of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) is to conduct research that will advance surface transportation through the application of innovative research and using connected-vehicle and infrastructure technologies to improve safety, state of good repair, economic competitiveness, livable communities, and environmental sustainability.

The goals of the Connected Vehicle/Infrastructure University Transportation Center (CVI-UTC) are:

- Increased understanding and awareness of transportation issues
- Improved body of knowledge
- Improved processes, techniques and skills in addressing transportation issues
- Enlarged pool of trained transportation professionals
- Greater adoption of new technology

Abstract

The purpose of this research and development activity was to build a mobile application with a low-distraction user interface appropriate for use in a connected vehicle (CV) environment. To realize their full potential, future CV applications will involve communicating information to and from drivers during vehicle operation. Mobile devices such as smart phones and tablets may be a reasonable hardware platform to provide this communication. However, there are concerns that a potential increase in driver interaction with CV applications may lead to driver distraction and possible negative impacts on driving safety. The prototype mobile device user interface that was designed and created during this project can be used to test new CV applications, validate their impact on driver safety, and inform future mobile device user interface standards for driving applications.

Acknowledgements

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Background

The objective of the Virginia Connected Corridor Pilot Deployment program is to move beyond the current state of connected vehicle (CV) technology toward the widespread adoption of CV systems. The purpose of the research and development activity presented in this report was to build a mobile application with a low-distraction user interface appropriate for use in a CV environment. To realize their full potential, future CV applications will involve communicating information to and from drivers during vehicle operation. Special care must be taken to create application interfaces that convey important message content to drivers without distracting them.

Applications being developed for this project address issues of road safety and mobility as well as the long-term goals of the Virginia Department of Transportation (VDOT) and Virginia road users.

The Northern Virginia Connected Vehicle Test Bed/Virginia Connected Corridor (VCC)

In 2014, VDOT and the Virginia Tech Transportation Institute (VTTI) introduced the Northern Virginia Connected Vehicle Test Bed/Virginia Connected Corridor (VCC), designed to enhance development and deployment of the next generation of vehicular technology (Figure 1). The VCC was established to provide a testbed where CV applications could be developed and tested in a challenging transportation environment. This corridor hosts over 46 Roadside Equipment (RSE) dedicated short-range communication (DSRC) radio units along Interstates 66 and 495 and Routes 29 and 50.

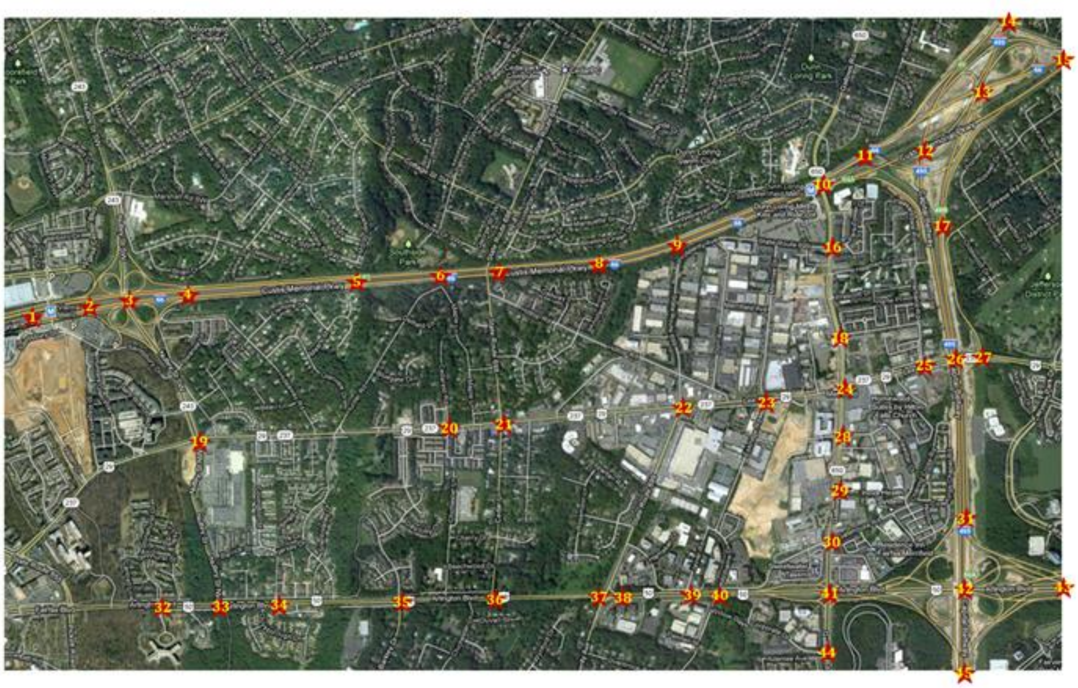


Figure 1. Northern Virginia Testbed and RSE locations.

The VCC initiative will aid in integrating connectivity with the transportation system to improve mobility, enhance sustainability, and save lives. While there are plans for statewide deployment of the mobile application developed in the project discussed here, the VCC will be the first area for alpha and beta testing due to its wealth of connectivity, availability of multimodal transportation options, and high levels of congestion. The region is one of the most congested locations in the nation, and has experienced a large increase in commuter delay over the past decade, as shown in Figure 2.

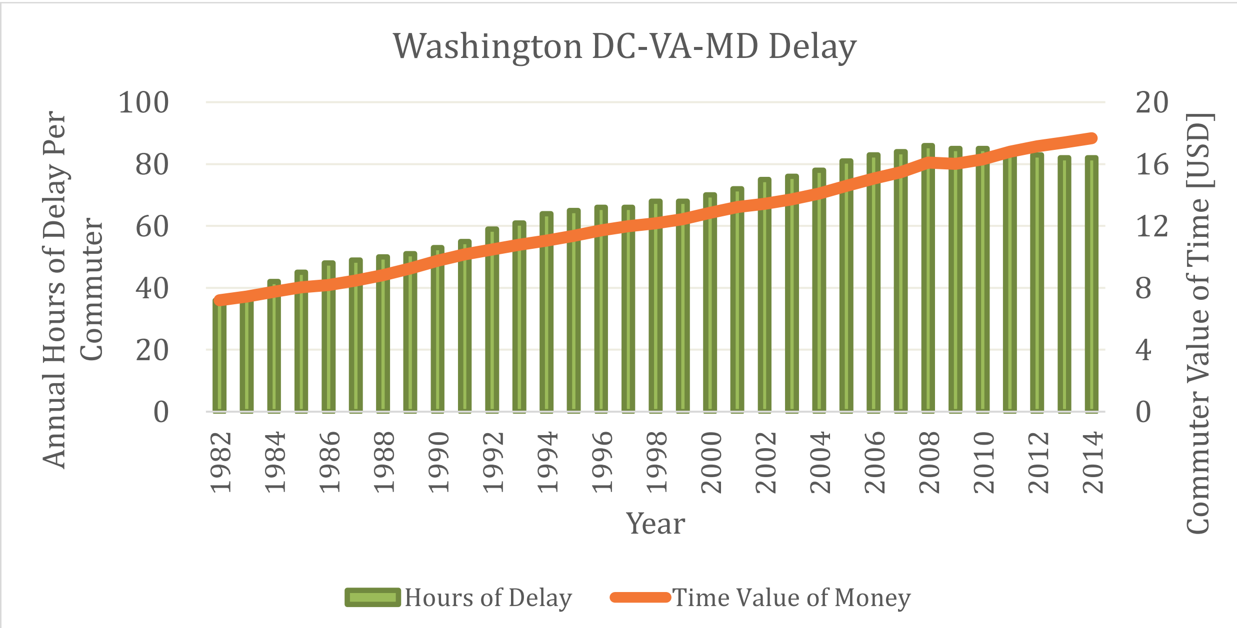


Figure 2. Increase in annual delay and value of commuters' time over the last decade [1].

The Cloud

The VCC's Cloud Computing Environment (shown in Figure 3) provides a centralized system supporting the management of CV message traffic between entities interacting on the corridor. The VCC Cloud may be accessed via a series of application program interfaces (APIs) and standardized data access methods that may be used by both internal and third party application developers. The resulting system is open to prospective users and transportation system operators as a means to test, develop, and evaluate CV solutions.

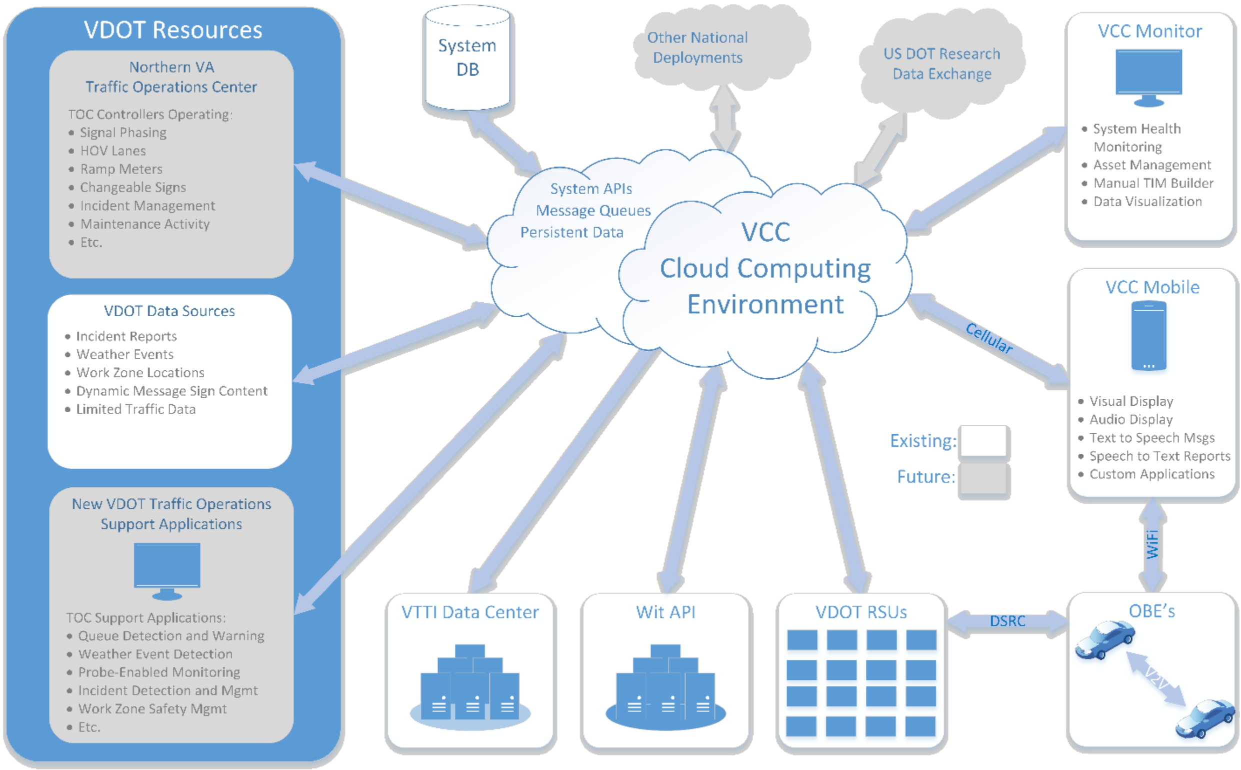


Figure 3. VCC Cloud Computing Environment.

The cloud provides connectivity to RSEs installed along the corridor in order to receive and broadcast messages to passing vehicles. Basic Safety Messages are received from vehicles equipped with DSRC on-board equipment (OBE) and traveler information message (TIM) data are broadcast back to the vehicles.

The addition of a cellular communications interface allows for bi-directional communications to cellular-only equipped devices and OBEs outside the range of DSRC RSE equipment. This additional service expands the area of coverage for the application to anywhere cellular data coverage is available and expands eligibility to a large number of consumer smart phone devices.

VCC Mobile Application Goals

The incremental goals of the VCC mobile application are extremely diverse. However, the completion of each micro-objective contributes to the overall goal of improving mobility for route users by providing them with more accurate information about the road ahead.

The interim goals of the VCC mobile application are as follows:

1. Provide enhanced communication capabilities.
    a. Support TIM communications and display.
    b. Receive vehicle speed and location data for use as a traffic probe in the future.
    c. Support crowdsourced on-road incident reporting.

2. Provide accurate information to users.
    a. Support interface to VDOT data sharing site to provide Dynamic Message Sign (DMS) data, traffic incident data, weather event data, and work zone data to better inform drivers of real time travel conditions.
    b. Provide accurate information to drivers about conditions along their intended route.
3. Ensure safety during use.
    a. Ensure low distraction and safe, easy use while operating a motor vehicle.
4. Support future applications.
    a. Location specific (Signal Phase and Timing [SPaT] and Active Traffic Management information depending on location)
    b. Call-for-help functions for drivers.
    c. Other third-party-developed applications.

Communications Strategy

According to a 2015 Pew Research Center Survey, 64% of American adults own a smartphone [2]. Northern Virginia has an established cellular network, and using Long-Term Evolution (LTE) wireless broadband technology at this stage of CV implementation is an ideal avenue for enabling high mobile application market penetration without further infrastructure investments.

When choosing a communications protocol for developing a CV technology application, it is important to consider scalability and the characteristics of the wireless protocols. The communications protocol must be the "correct fit" for the application being utilized. The VCC Mobile Application sends drivers messages that fit the cooperative traffic and infotainment classification (under certain definitions). Due to the potential for system latency in the cellular data communications environment, active safety messages requiring immediate response are not transmitted using LTE protocols.

Table 1. Application Performance Standards [3]

Parameters	Latency	Coverage Range	Min. Trans. Freq.	Data Rate
Active Safety	Low (≤ 100 ms)	Short–Long (300 m–20 km)	10 Hz.	Low–Medium (1 to 10 kbps)
Cooperative Traffic	Medium (≤200 ms)	Short–Medium (300 m– 5 km)	1–10 Hz.	1–tens of kbps
Infotainment	Longer (≤ 500 ms)	Short–Long (varies)	1 Hz.	1 to several hundred kbps depending on content

Table 2. Characteristics of DSRC and LTE Communications [4]

Protocol	Range	Delay	Call Setup Time	V2V[1] Local Broadcast	V2V Multi-hop	I2V[2] Local Broadcast	V2I[3] Bidirectional
DSRC	~300 m	10 ms	N/A	Yes	Yes	Yes	Yes
LTE	10s m – 100 km	10's ms	~ 50 ms	With server	With server	Not offered by all networks	Yes

[1]Vehicle-to-Vehicle, [2]Infrastructure-to-Vehicle, [3]Vehicle-to-Infrastructure

System Architecture

The VCC Mobile Application powers on once the vehicle starts and the phone receives power. The smartphone's global positioning system (GPS) location features activate at application startup. Speed and location data from the smartphone are transmitted via cellular network to the VCC Cloud at regular intervals throughout the drive. Vehicle location may also be obtained through cell signal triangulation or base station Cell-ID if the primary means of obtaining data (i.e., GPS satellites) is unavailable. The internet transmits application data between the cellular network and the VCC Cloud. Once at the network server level, the location information is used to identify relevant message information to be transmitted back to the user from the VDOT data sharing site as well as other sources, such as the Wit API (a speech to text processing program).

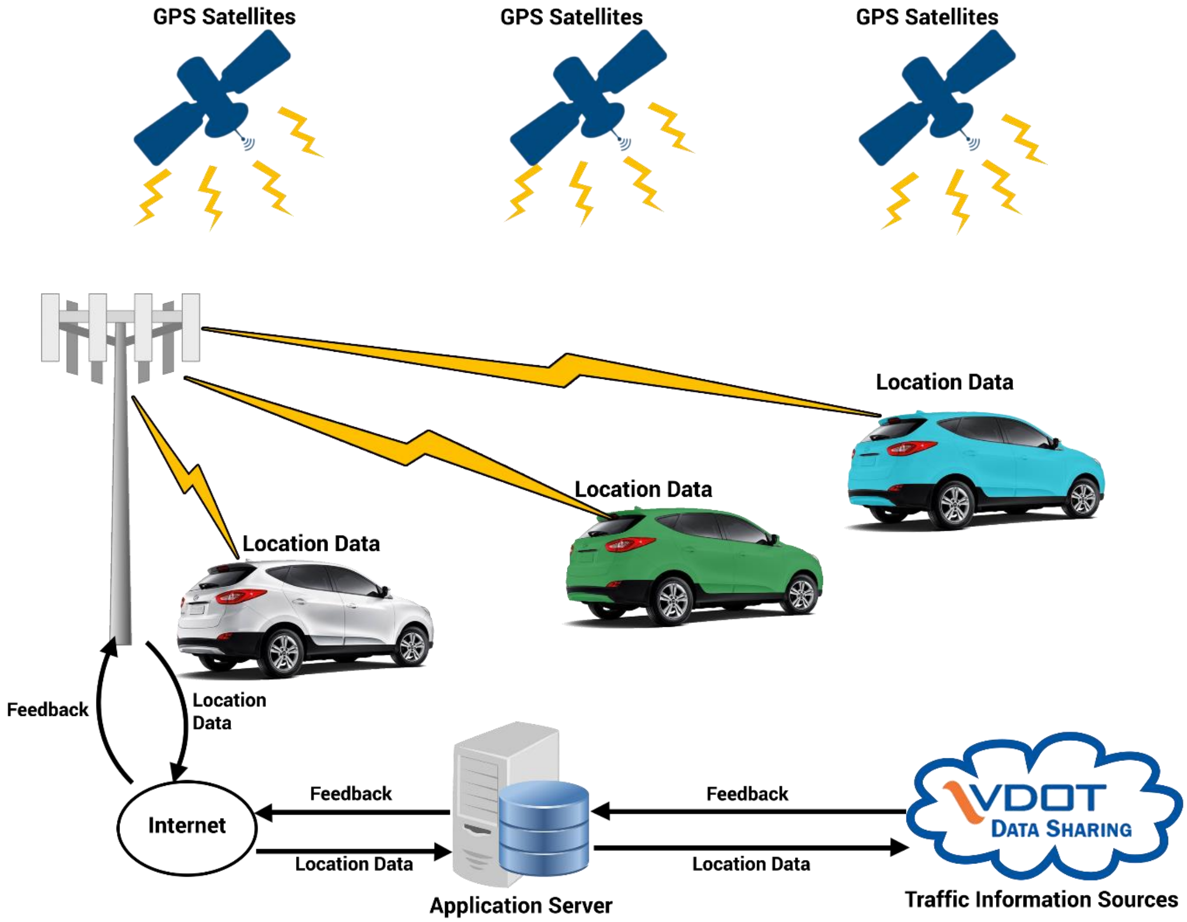


Figure 4. Communication structure of the VCC Mobile Application.

Software Development

The VCC Mobile application was developed on the Google Android platform for smartphones (http://developer.android.com/index.html) with Java Development Kit (JDK) 1.6 and an Android SDK4.1.2. The application's primary function is locating the vehicle on a regular basis and sending this location information to the server to query for events stored in the pre-existing traffic information databases. After the query is complete, the feedback from the server is converted into a TIM, which is displayed as a pending alert on the wireless device until such time that the information becomes relevant based on GPS location. At that point, Wit API, a text to speech synthesis program, reads the message aloud to the driver.

The server is responsible for receiving, analyzing, and providing feedback for travel data transmitted by the end-user device. An open source relational database management system (RDBMS), PostgreSQL, is used to store and process real-time data. These data include each GPS location, date and time stamp, travel direction, speed, and closest point on the link generated from the map matching process.

The communication between the server and client is though the 3G/4G/LTE cellular network and the internet. The application uses the "ServerSocket" class in the Android SDK, which implements a server socket that waits for incoming client connections. A server socket handles the requests and sends back an appropriate reply.

The mobile application will be available on the Google Play Store for download. Updates will be posted on the Google Play Store and automatically downloaded to phones in a similar manner to other mobile applications.

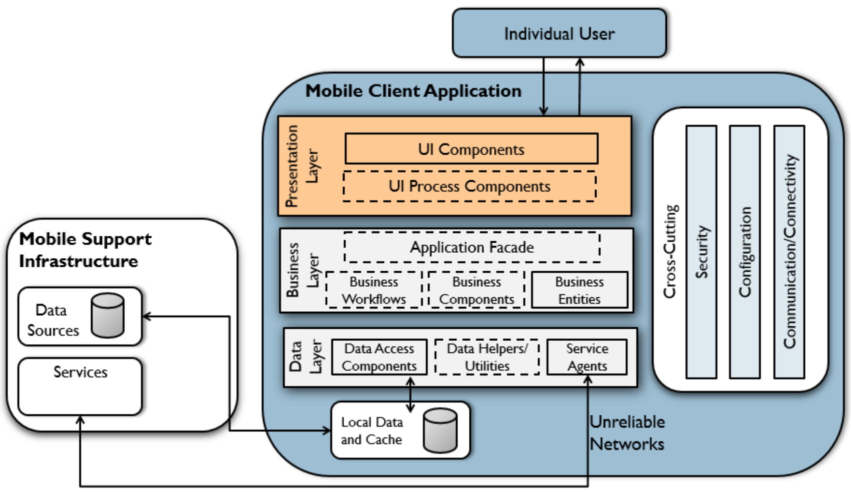


Figure 5. Mobile application diagram.

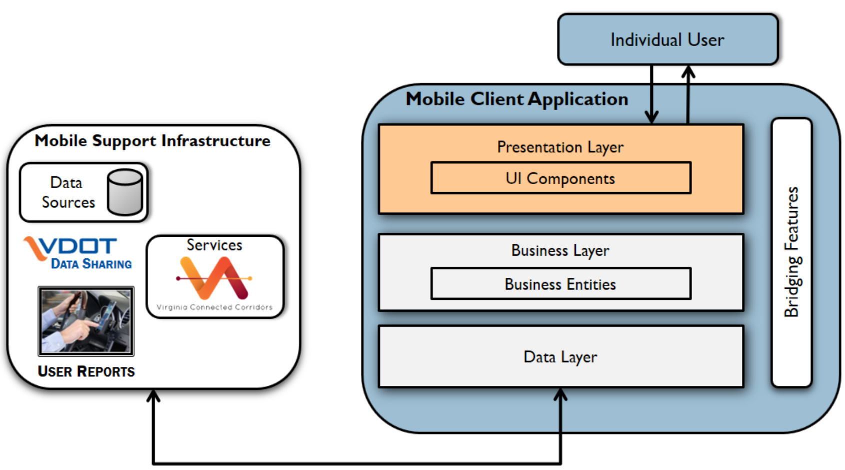


Figure 6. Simplified mobile application diagram.

The VCC mobile application interfaces with the VCC cloud computing environment to access a variety of information in TIM data format. This information is constantly updated with data gathered by VDOT Operations computing systems and the data sharing portal for the 511 Virginia driver information system. Informational categories include the following:

- Traffic congestion messages indicating the location and duration of traffic backups
- Traffic incident events such as crashes, stalled vehicles, special incidents (e.g., sporting events, concerts, etc.) and other traffic relevant roadway anomalies
- Special weather events such as slick bridges, snow packed roads, standing water, fog, and rain
- Work zone information, including general work zone locations and speeds, specific areas of work zones where work is actively occurring, and special driver instructions such as lane shifts, flagging operations, etc.
- DMS content such as information currently displayed on overhead signs along the Northern Virginia transportation corridors

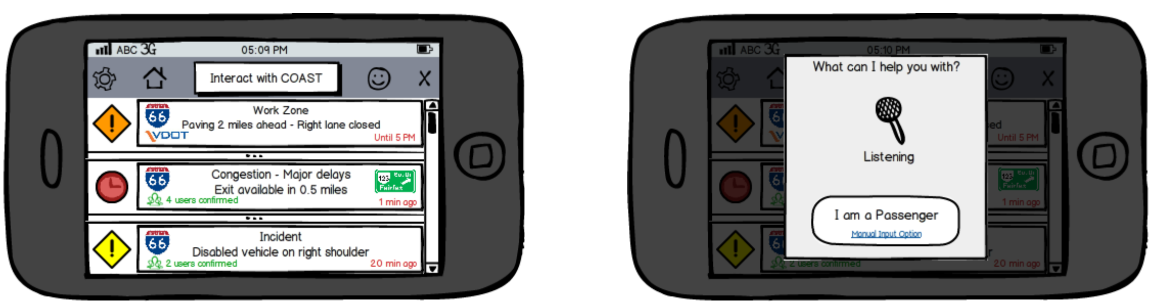
Additional informational categories planned for the near future include a) active traffic and demand management Active Traffic and Demand Management (ATMD)/Advanced Traffic Management System (ATMD/ATMS) information about prescribed travel speeds, dynamic lane operations, and high occupancy vehicle (HOV) requirements and b) emergency medical services (EMS) information about the presence and status of emergency responder vehicles

Drivers may use the system to report various roadway conditions back to the VCC Cloud. These reports are classified, validated, and converted into messages to assist other drivers in the area. The VCC mobile application completes the link between the VCC Cloud and its available data sources and the end-user driver, making it possible to deploy advanced messaging capabilities (or any application outputs) to large numbers of drivers traveling on the VCC.

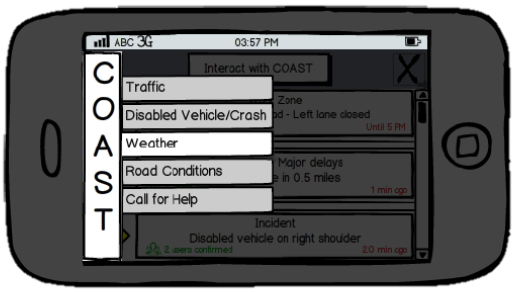
Mobile Application User Interface Development

Initial Application Design

The VCC Mobile Application went through an iterative design process, and was initially called COAST (COoperative Active Safety Tool) (Figure 7). This iteration featured a manual user interface option for passengers that was later removed to comply with the Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices [5].



(a) (b)



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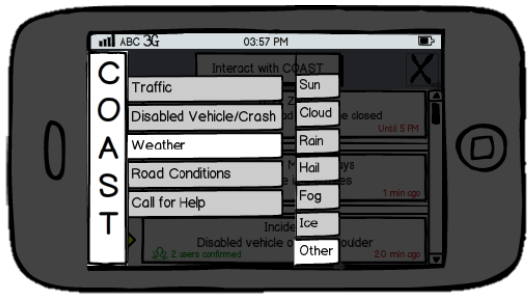

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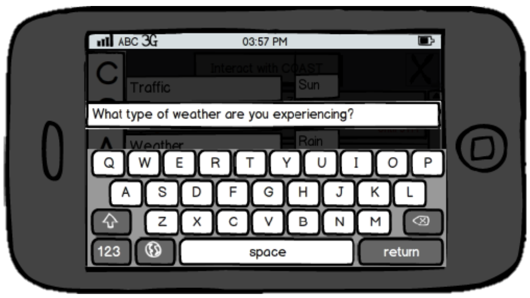

(e)

Figure 7. Initial design of the VCC Mobile Application: COAST (COoperative Active Safety Tool).

The final mobile application user interface was designed to minimize driver distraction per the aforementioned guidelines while maximizing the useful information transmitted and received by drivers.

Visual Features

Figure 8 shows the final mobile application interface. A discussion of the application's design and features is provided in the following sections.

Figure 8. Layout of the mobile application main screen.

Perception of Information

There are two ways of understanding how perception works. Top down processing involves the recognition of patters from contextual information. In bottom up processing, perception begins at the sensory input, or stimulus. Bottom up processing can, therefore, be described as data driven.

The amount of information presented to the driver was a significant consideration given the limited screen real estate available for displaying the text-based messages. In addition, due to the demand of the driving task, engaging in any activity that increases eyes off road time also increases crash risk. When using a display with limited size in a driving environment, there will necessarily be a tradeoff between top-down and bottom-up processing. The display design of the VCC Mobile Application user interface is an intersection of top-down and bottom-up information processing principles. In Figure 9, the two dashed lines represent different amounts of contextual redundancy: (a) high context of printed text and (b) low context of isolated word strings.

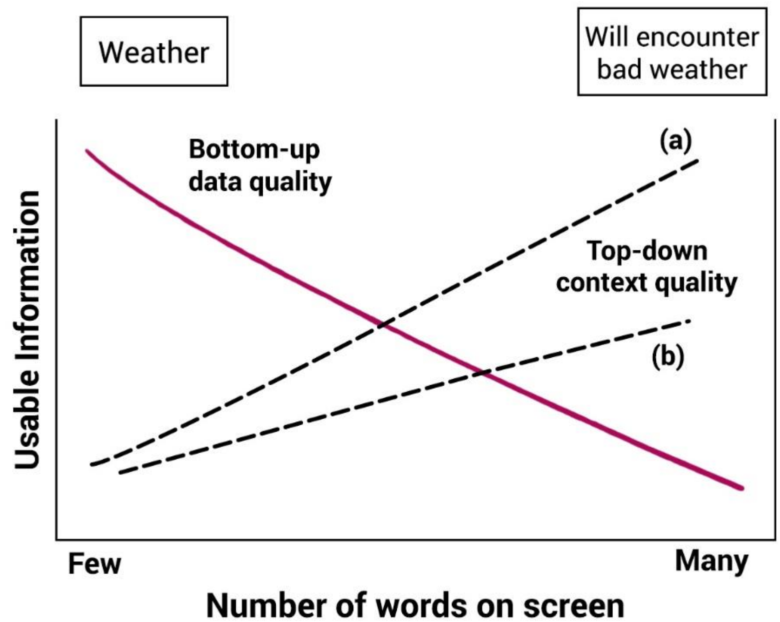

Figure 9. The trade-off between top-down and bottom-up processing in display of limited size (adapted from Wickens, et al. [6]).

Message Design

The message content includes the nature of the event (e.g. maintenance, crash, hazard), the location of the event (i.e., I-66, I-99, U.S. 460), and the impact of that event (e.g., east right shoulder closed, delays expected). The driver's proximity to the event is rounded to intervals of hundreds and tens to prevent drivers from being overload with an unnecessary level of specificity.

According to Carryl, "For auditory displays, high-complexity displays contain over nine information units and take over five seconds to process. Conversely, low-complexity displays contain three to five information units and require less than five seconds to process." If the auditory message is too complex, it will likely exceed the working memory capacity limitations of the driver and not be retained [7]. Auditory messages for the VCC Mobile Application include event nature, lane level specificity if available, and impact of the hazard on the drivers' commute. Route level information was added to auditory displays for an added layer of redundancy. In the event that drivers intend to change routes, they can decide if this route level information is relevant to them. The simplified nature of our auditory messages, containing as few words as possible, allows drivers to understand the situation ahead of them with the minimum amount of information required.

Icon Design

Icons should be clearly distinguishable from one another in global shape, and should be easy for users to interpret. Redundant labels are recommended for icon-heavy user interfaces (spatial and verbal). Icons facilitate top-down processing by perceptual mechanism, which is the part of the brain that makes sense of the surroundings, and are often useful in a mixed cultural setting. The icons used in the VCC Mobile Application's user interface are included in Appendix A.

The visual display was designed to allow drivers to gather essential information quickly with single, short glances. The main features of the user interface include the information tile, user report button, and the active alert tile.

Earcon Design

An earcon is a brief distinctive sound that is used to represent a specific event or convey other information. The VCC Mobile Application features six earcons in addition to the Wit message text-to-speech synthesis application, which is described in further detail in the Speech to Text API Training section. The characteristics and functional purpose of the earcons are described below.

New Active Alert

The New Active Alert earcon is 2.5 seconds long; however, only 1.2 seconds of the tone are audible. The peak frequency of the tone is 523 Hz.

Cancel

If drivers decide to cancel a user-initiated report (described later in the Make a Report section), the Cancel earcon will play. This earcon consists of two pulses that are 0.077 seconds in duration with an interpulse gap of 0.005 seconds. The first pulse has a peak frequency of 1,048 Hz; the peak of the second pulse is 880 Hz.

Record Stop

Upon completion of the user-initiated report, an earcon notifies drivers that the recording has finished. This earcon consists of two 0.080 second pulses with an interpulse gap of 0.003 seconds. The first pulse has a peak frequency of 880 Hz.; the peak frequency of the second pulse is 1,048 Hz.

Send

When the user-initiated report is sent to Wit for processing, an earcon consisting of nine pulses is activated. The duration and peak frequency of each pulse and interpulse gap is shown in Table 3.

Table 3. Send Earcon Characteristics

Pulse	Duration [s]	Peak [Hz.]	Gap	Duration [s]
1	0.049	701	1	0.076
2	0.049	1,049	2	0.076
3	0.048	1,398	3	0.076
4	0.047	1,049	4	0.077
5	0.052	1,397	5	0.079
6	0.047	1,049	6	0.08
7	0.047	1,398	7	0.203
8	0.047	702	8	0.08
9	0.047	1,049	—	—

Try Again

If Wit is unable to determine what drivers have said, they will receive an earcon indicating they should try again. This earcon consists of two pulses, both with a peak frequency of 343 Hz. The first pulse has a 0.132 second duration with an interpulse gap of 0.011 seconds; the second pulse has a duration of 0.328 seconds.

Information Tile

The information tile (Figure 10 and Figure 11), featuring an icon of the general event class, is shown when entering the active geographic region for the message for quick reference, followed immediately by fixed text with additional event detail when available. This tile allows drivers to quickly see the nature of events occuring on the roads ahead.

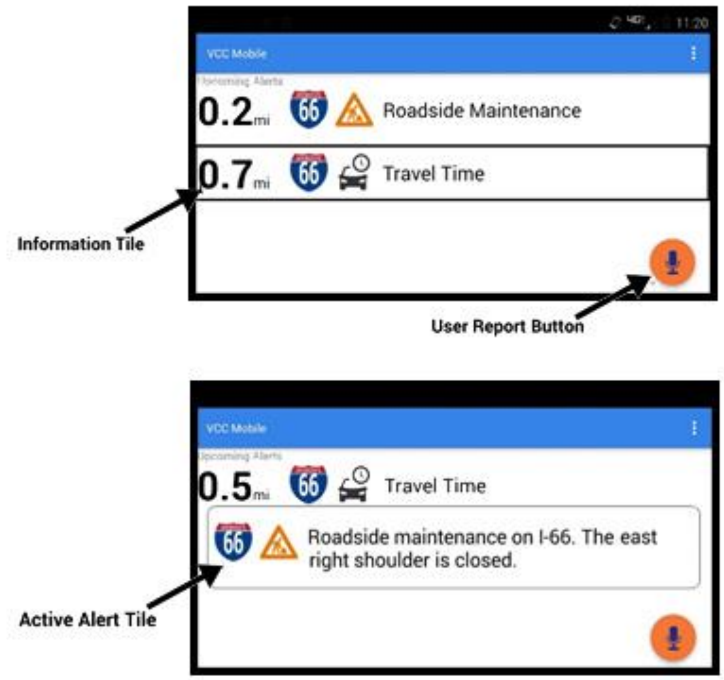

Figure 10. Information tile: main application features.

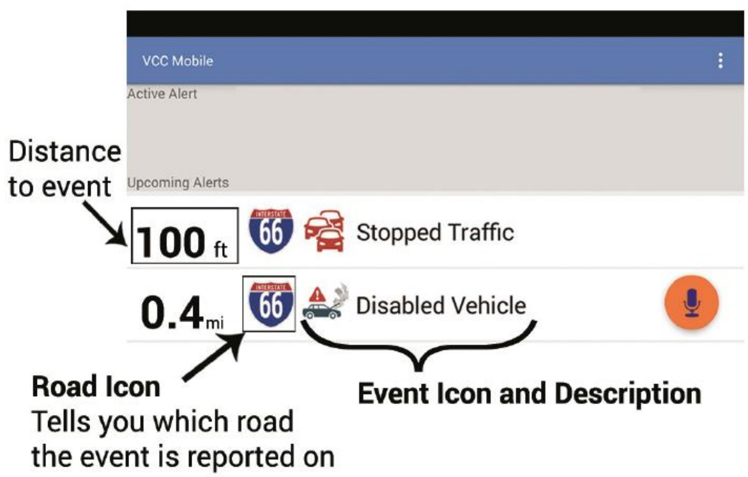

Figure 11. Information tile layout.

Additional upcoming event information can be obtained by tapping on the information tile, which will cause the event tile to appear and the information there to be read aloud. Presenting the event information aloud reduces eyes off road time compared to traditional pure text information systems.

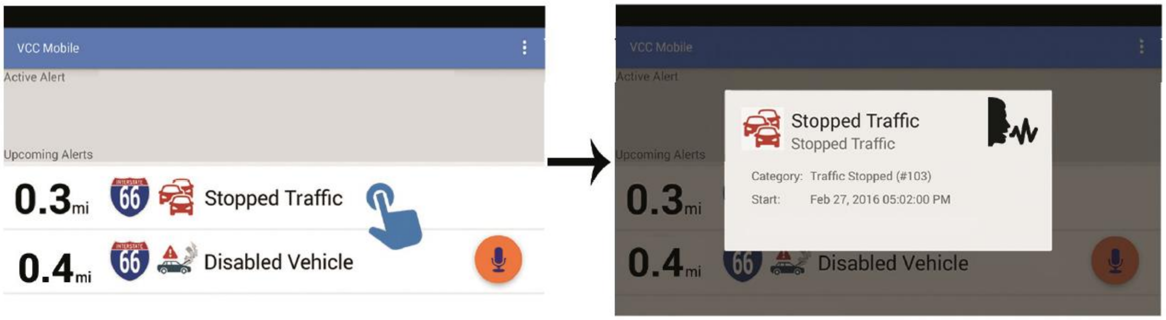

Figure 12. Event tile: drivers can tap the information tile to receive more information about the event.

Information Prioritization

Messages are assigned a high to low priority level from 1 to 7. Messages with higher priority supersede messages in the same region with lower priority and will be displayed (become active) first. Priority schemes have not been implemented in the current version of the application, but will be implemented in future application iterations. Priority schemes are particularly useful with message types such as EMS and a mobile connected work zone application.

Cone of Interest

To determine which information is pulled from the server for the immediate area, two overlapping geospatial bounding regions called "cones of interest" were defined relative to the position of the wireless device. The vertex of the cone corresponds to the current position of the smartphone and widens as the vectors lengthen. One cone is a long-range cone, which has a smaller angle to provide ample warning of alerts that are immediately in front of the phone. The second cone is a short-range cone with a wide angle. This ensures that, in the event of a route change or moving hazard on an adjacent street, anything close to the smartphone is presented to the user. Any advisory that falls within one of these two cones is displayed on the user alert list. Figure 12 shows an example of how the cones of interest function in the application.

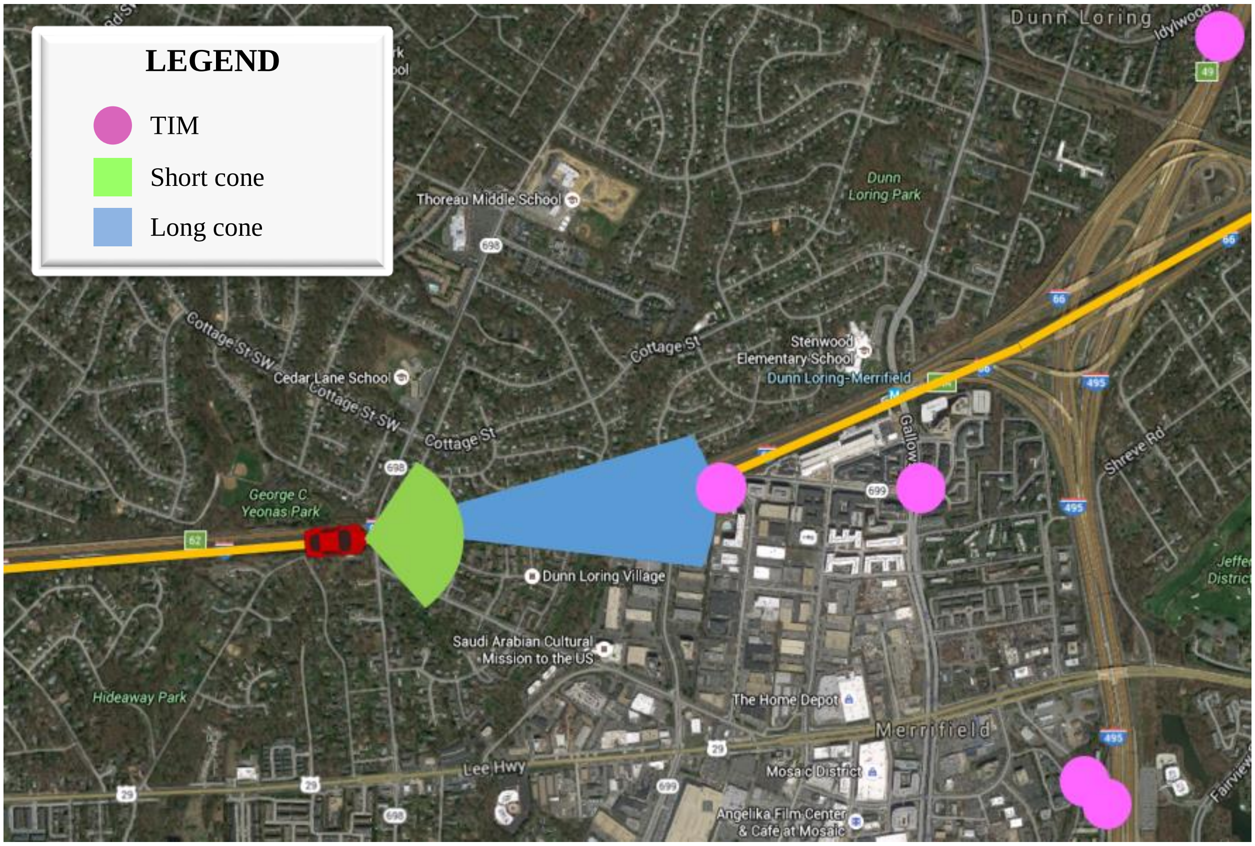

Figure 13. Cone of interest projected from the front of the vehicle in the direction of travel.

Message Consolidation

Research has shown that multiple messages within a short time interval can annoy drivers, and may result in making the driving task more difficult [8] or cause drivers to discontinue use of the application. Message consolidation groups similar messages within a specific geospatial region together and displays only the most relevant few to the user. For example, in Figure 14, the work zone messages could be consolidated from four messages to one or two—one message alerting drivers of the work zone activities and one informing them of the presence of workers as they near their location.

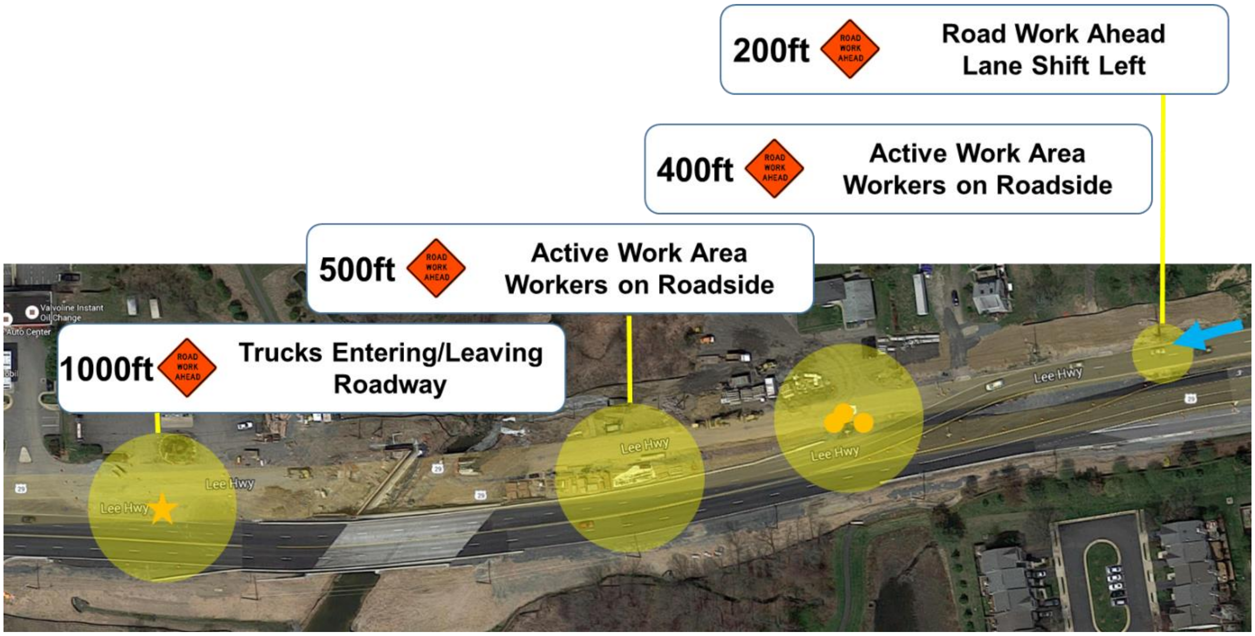

Figure 14. Multiple work zone messages are ideal candidates for consolidation.

User Actions

Make a Report

The VCC Mobile Application allows drivers to report traffic conditions and observed events on the roadways they are traveling on. This process uses a Wit speech to text synthesis program with text classification.

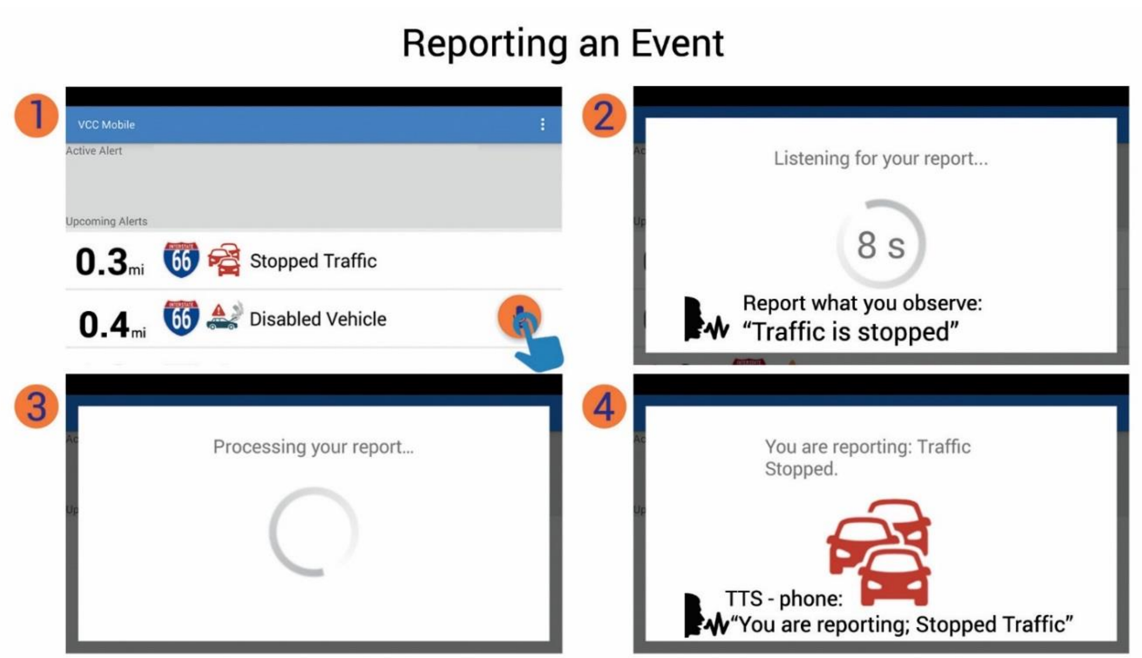

Figure 15. The protocol for reporting an event on the VCC mobile application.

To report an event, drivers tap the microphone button located on the bottom right of the user interface, at which point they have eight seconds to verbally state their report. An auditory tone alerts the user of the opening and closing of the audio reporting channel. Upon the closure of the audio reporting channel, the speech is processed by the Wit API, binned in what the program deems to be the appropriate category, and text-to-speech synthesizers read the interpretation of the report back to the driver (Figure 15-4).

Drivers can retry the process at any point by tapping the screen, and can cancel the reporting process by swiping the screen to the left. Drivers can also submit immediately with an upward swipe.

Speech to Text API Training

The Wit API uses natural language processing techniques and speech recognition engines to allow for sentences spoken by the driver to be turned into a structured set of data. This requires training the program to identify the specific wording of intents, expressions, and entities as defined below.

Training involves providing the server with spoken text phrases that drivers might use when encountering a road issue and manually classifying them within the database until the algorithm "learns" how to classify them automatically. Following is a simplified example of how the learning process takes place using three basic classifications: intents, expressions, and entities.

Intents: Broad classification of events (e.g. disabled vehicles, EMS activity, crashes)

Expressions: Make up (define) the intents

Entities: Provide an additional level of detail to the expression if they are available.

- Expression: There is a disabled vehicle on the right shoulder.
- Intent: Disabled Vehicle
- Entities: Lane Location

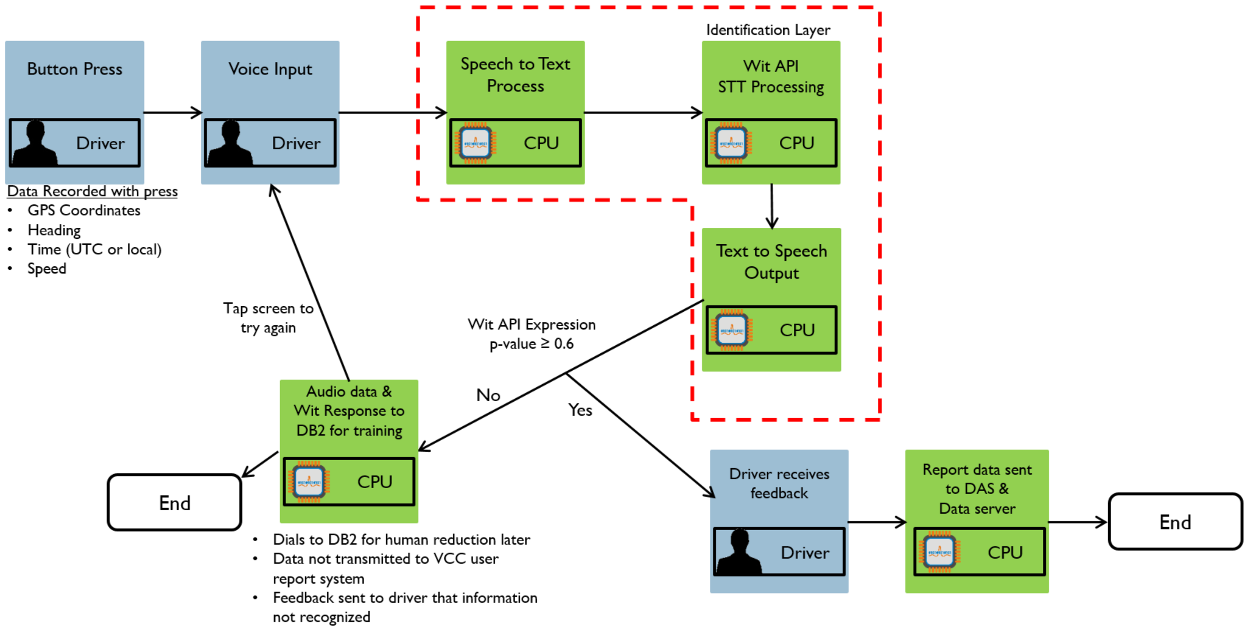

Figure 16. Flow diagram of speech-to-text software and incident reporting.

Additional Functionality and Third Party Application Development

Active Traffic and Demand Management (ATMD)/Advanced Traffic Management System (ATMS)

This functionality is only available on I-66, where it provides information about lane level restrictions, including hard shoulders, HOV lanes, and lane-specific speed limits. This display mirrors the conditions that are present on the Interstate overhead gantries, and is displayed continuously when drivers are on I-66 during the hours that restrictions are in effect.

Figure 17. Example of TIM messages displayed in the VCC mobile application with ATMD/ATMS display.

Worker Application

This application would help keep road workers safe by communicating their location and status to connected vehicles. Following is a brief description of the projected workflow for the Worker App.

- Workers carry smart phone with Worker App
- Workers select an activity
- Workers select duty status
- Worker App sends position and activity data to VCC Cloud
- VCC Cloud processes messages and creates advisories and streaming alerts for drivers
- Messages are conveyed to VCC Mobile app to display to driver based on position, speed, direction, etc.

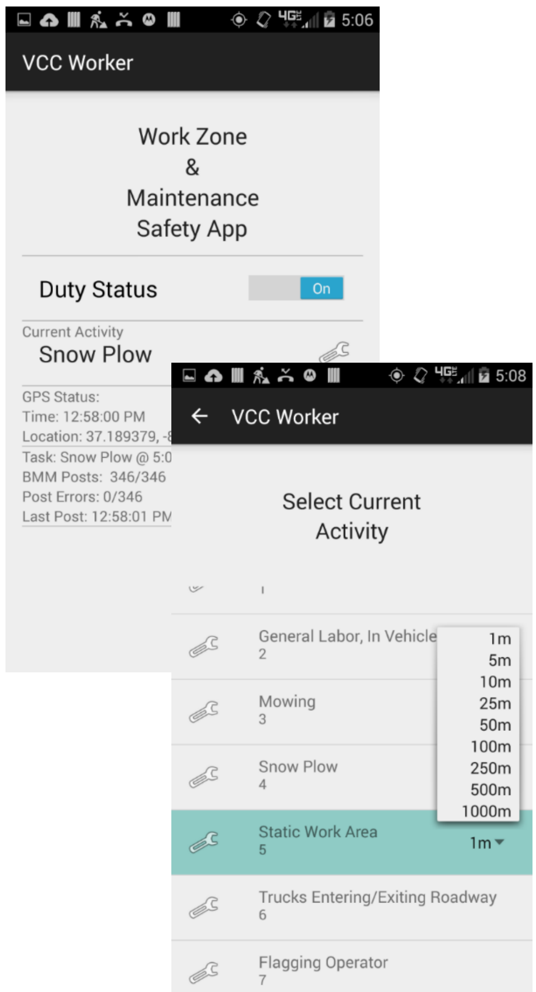

Figure 18. VCC Worker Application.

Emergency Service Vehicle Application

The EMS vehicle application is for demonstrative purposes at this time, and functions in the same fashion as the Worker Application. The EMS vehicle is equipped with a smartphone that transmits its coordinates and heading via the wireless network. When the EMS vehicle nears an equipped passenger vehicle, the driver of the passenger vehicle will receive a notification of the EMS vehicle's relative position and proximity.

Application Testing with a Naturalistic Driving Study (NDS)

Smartphone Display Description

The smartphone selected to run the mobile application was a Droid Maxx by Motorola. The phone has an Android 4.4.4 Kitkat® operating system and hosts a 5-inch super active-matrix light-emitting diode (AMOLED) display with 1280×720 screen resolution. The device was large enough for text alerts to be seen clearly from the driver's seat, yet was small enough to not interfere with the task of driving or manipulation of items on the entertainment stack.

Device Mounting Location

The smartphone was positioned such that it was located slightly offset from the steering wheel, near the vehicle's heating, ventilation, and air conditioning system (Figure 19). This is considered a high head-down display and was selected due to its proximity to the driver's field of view. This fixed mounting location eliminates any requirement to find, orient, and activate a phone interface. This mounting location features one of the minimum distances for a driver's eyes to travel from the forward roadway while executing functions and reading text.

Figure 19. Exemplar device mounting location.

Naturalistic Driving Study

Fifty participants who regularly drive on I-66, U.S. 29, U.S. 50 or I-495 in Northern, VA will be recruited to participate in the study. Each participant's vehicle will be equipped with VTTI's NextGen Data Acquisition System (DAS). The DAS is the same system used in the Second Strategic Highway Research Program Naturalistic Driving Study (SHRP2 NDS). In the proposed NDS, the DAS will continuously record video of the driver's face, the forward roadway, an over-the-shoulder view of the driver's hands and lap area, a view of the instrument cluster, and a view of the foot well and drivers' feet. The DAS will also record speed, throttle position, brake application, acceleration, lane position, turn signal activation, and GPS position. VTTI will use its own mission control software to monitor vehicle location, data storage, and mileage incurred over the course of the data collection period.

Two categories of audio data will also be captured for use during the study. Each type of audio and its purpose is described below.

- Incident button audio includes audio captured when drivers press the red incident button on the DAS head unit. Pressing this button allows them to voluntarily record 30 seconds of audio that they want a researcher to hear, providing them with an opportunity to report any issues related to their driving or use of the technology.
- Advaned Traveler Information System application audio includes the verbal reports of driving conditions collected from drivers when they press the “report” button on the application screen. The verbal report is transmitted to WIT to interpret the voice phrase content and map it to an intended report category. The category text is then returned to the VCC Mobile Application for the driver to confirm, restate, or cancel. The result of the report is used to generate new messages about localized roadway conditions for subsequent drivers. This audio will also be used in the development of a speech recognition system for drivers to report roadway conditions in a non-distracting manner.

Participants will be asked to complete a set of driver assessments on or near the date of installation of the data collection equipment. The assessments will include cognitive and physiological tests administered via electronic computer programs. Some tests will be completed onsite during installation and others may be completed using an online questionnaire administration system from participants’ personal computers.

This study will also require collection of data indicating how and when drivers engage and respond to the connected systems so researchers can evaluate the impact of these interactions on driver safety and behavior. The data are essential to 1) provide objective measurement for the type and magnitude of impact on driving safety and behavior, 2) understand when drivers interact with the connected and automated systems, 3) understand the state of drivers based on physical, medical, and cognitive assessment responses, and 4) to understand the context of the driving situation when these interactions occur.

Conclusion

This study will provide an evaluation of the use of a connected vehicle traveler information system in a naturalistic environment. The research team will measure safety benefits and driver responses to real time information presented to drivers through a mobile phone application interface while they go about their day-to-day driving. This study will look at whether the use of these systems together presents any safety concerns. The results will allow developers to identify and fix any safety or usability issues in future products.

After successful completion of the alpha group testing, beta groups will be defined to invite users to download the application onto cell phones and use the application on their own devices. Modes of broader distribution on the Google Play Store are anticipated upon positive response from the beta test phase.

References

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Appendix

Appendix A – Icon Classification

Include in Queue?	Main Classification	Sub-Class	(c,sc)	Icon
YES	TRAFFIC/CONGESTION	TRAFFIC_CLEARING	101	
		TRAFFIC_SLOWING	102	
		TRAFFIC_STOPPED	103	
		CONGESTION	204	
		DMS_BACKUP	613	
		traffic_clearing	701	
		traffic_slowing	702	
		traffic_stopped	703	
YES	INCIDENT	VEHICLE_ACCIDENT	201	
		MULTI_VEH_ACCIDENT	202	
		DISABLED_VEHICLE	203	
		TRACTOR_TRAILER_ACCIDENT	205	
		SECURITY_POLICE	206	
		BRIDGE_TUNNEL_STOPPAGE	207	
		BRUSH_FIRE	208	
		VEHICLE_FIRE	209	
		SPECIAL_EVENT	308	
		SPORTING_EVENT	310	

Include in Queue?	Main Classification	Sub-Class	(c,sc)	Icon
		DMS_BRIDGEOPENING	606	
		DMS_DISABLED	611	
		DMS_ACCIDENT	612	
		Crash_left_LANE	704	
		crash_left_SHOULDER	705	
		crash_middle_LANE	706	
		crash_right_LANE	707	
		crash_right_SHOULDER	708	
		crash_travel_lane	709	
		disabled_left_LANE	710	
		disabled_middle_lane	711	
		disabled_right_LANE	712	
		disabled_TRAVEL_LANE	713	
		disabled_vehicle_left_SHOULDER	714	
		disabled_vehicle_right_SHOULDER	715	
		hazard_in_road_ANIMAL	716	
		hazard_in_road_OBJECT	717	
		hazard_in_road_POTHOLE	718	
		moving_hazard_near_road	719	
		road_condition_FLOODING	721	
		road_condition_SLICK	722	
YES	WORK ZONE	CONSTRUCTION	301	
		BRIDGE_WORK	302	
		MOWING	303	
		PAVING	304	
		POTHOLE_PATCHING	305	
		GUARDRAIL_REPAIR	306	
		MAINTENANCE	307	
		SIGNAL_REPAIR	309	
		DMS_ROADWORK	602	

Include in Queue?	Main Classification	Sub-Class	(c,sc)	Icon
		hazard_workzone	731	
YES	TRAVEL TIME	DMS_TRAVELTIME	601	
		DMS_NUMBER	604	
YES	GUIDANCE	DMS_DESTINATION	607	
NO	HOV/LANE MANAGEMENT	DMS_HOV	603	
		DMS_HOV_XTRA	609	
YES	WEATHER	SNOW	401	
		RAIN	402	
		STANDING_WATER	406	
		THUNDERSTORM	403	
		ICE	404	
		DMS_ICY	614	
		FOG	405	
		DMS_FOG	610	
		WIND	407	
		weather_clouds	723	
		weather_fog	724	
		weather_hail	725	
		weather_ice_sleet	726	
		weather_OTHER	727	

Include in Queue?	Main Classification	Sub-Class	(c,sc)	Icon
		weather_rain	728	
		weather_snow	729	
		weather_hurricane	732	
		weather_tornado	731	
		weather_sun	730	
YES	EMS	EMS	500	
		EMS_Activity	732	
MAYBE	Infrastructure	Infrastructure_BROKEN	720