Cooperative Intersection Collision Avoidance System – Stop Sign Assist (CICAS-SSA)

CONCEPT OF OPERATIONS

Version 1.0

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Revision History

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0.1	Preliminary Draft	7-12-2007	CICAS-SSA ConOps PRELIM DRAFT 7-12-07.doc
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1. Background and Scope

The United States Department of Transportation (USDOT) is working in partnership with automotive manufacturers and state and local departments of transportation to pursue an optimized combination of vehicle-based, infrastructure-based and vehicle-infrastructure cooperative systems that will be designed to address a full set of intersection crash problems. The national Cooperative Intersection Collision Avoidance Systems (CICAS) effort is divided into four project areas:

- CICAS-CBAT (Cost Benefit Analysis Tool)
- CICAS-V (Violations)
- CICAS-SLTA (Signalized Left-Turn Assist)
- CICAS-SSA (Stop Sign Assist)

Led by the Minnesota Department of Transportation (Mn/DOT) and University of Minnesota, CICAS-SSA targets the national problem of crashes at rural thru-stop intersections; particularly those where lower speed, lower volume roads intersect high speed, high volume expressways. In May 2007, USDOT merged CICAS with the Vehicle Infrastructure Integration (VII) program. Although the CICAS-SSA project will primarily evaluate information delivery via roadside signing, the Minnesota team will also build upon previous research to facilitate cooperative vehicle-infrastructure components that are aligned with VII. For example, the alerts and warnings developed through CICAS-SSA will involve both Vehicle to Infrastructure (V2I), and Infrastructure to Vehicle (I2V) communication. Furthermore, CICAS and other VII applications require state map information (i.e., roadway geometry, vehicle speed and location information, and traffic control device information as well as possibly other vehicle dynamic information) to perform their functions. CICAS-SSA will examine various options for what, when and how data will be cooperatively shared between the vehicle and the roadside infrastructure. One option may require the infrastructure to perform threat assessments, and warn affected drivers via roadside or in-vehicle signing. Another option may be to provide the state map to properly equipped vehicles, thereby allowing vehicles to perform threat assessments and deliver in-vehicle warnings.

The CICAS-SSA research is separated into two areas of work. First is a three-year research effort to develop a gap algorithm and Driver Infrastructure Interface (DII) for algorithm validation. The research effort will also examine the role of system architecture and how it affects both V2I and I2Vcommunication, which is essential to both infrastructure and vehicle-based driver interfaces. The second component of CICAS-SSA is a two-year field operational test under which the safety benefits and driver acceptance of the system can be validated. Research and field testing will be conducted at the intersection of US52 and County State Aid Highway (CSAH) 9 in Goodhue County, Minnesota.

This Concept of Operations describes how the initial CICAS-SSA system is envisioned to be used in a fully deployed environment. It is presented from various stakeholder perspectives in terms of requirements and functionality. The Concept of Operations is being developed to:

- Facilitate stakeholder agreement on why the system is being developed, how the system will be operate, who will be responsible for the system, and what the lines of communication will be among stakeholders
- Define the environment in which the system will operate
- Support derivation of high-level functional and performance requirements

The intended audience for this document includes:

- Federal, state, county and city transportation agencies
- Public safety community
- Vehicle manufacturers
- Traffic operations personnel
- Transportation agency planners
- Suppliers of CICAS-SSA components
- Standards development organizations
- Research and development centers that may conduct future CICAS research
- Other CICAS project teams – V, SLTA and CBAT
- Other VII application teams

1.1. Purpose

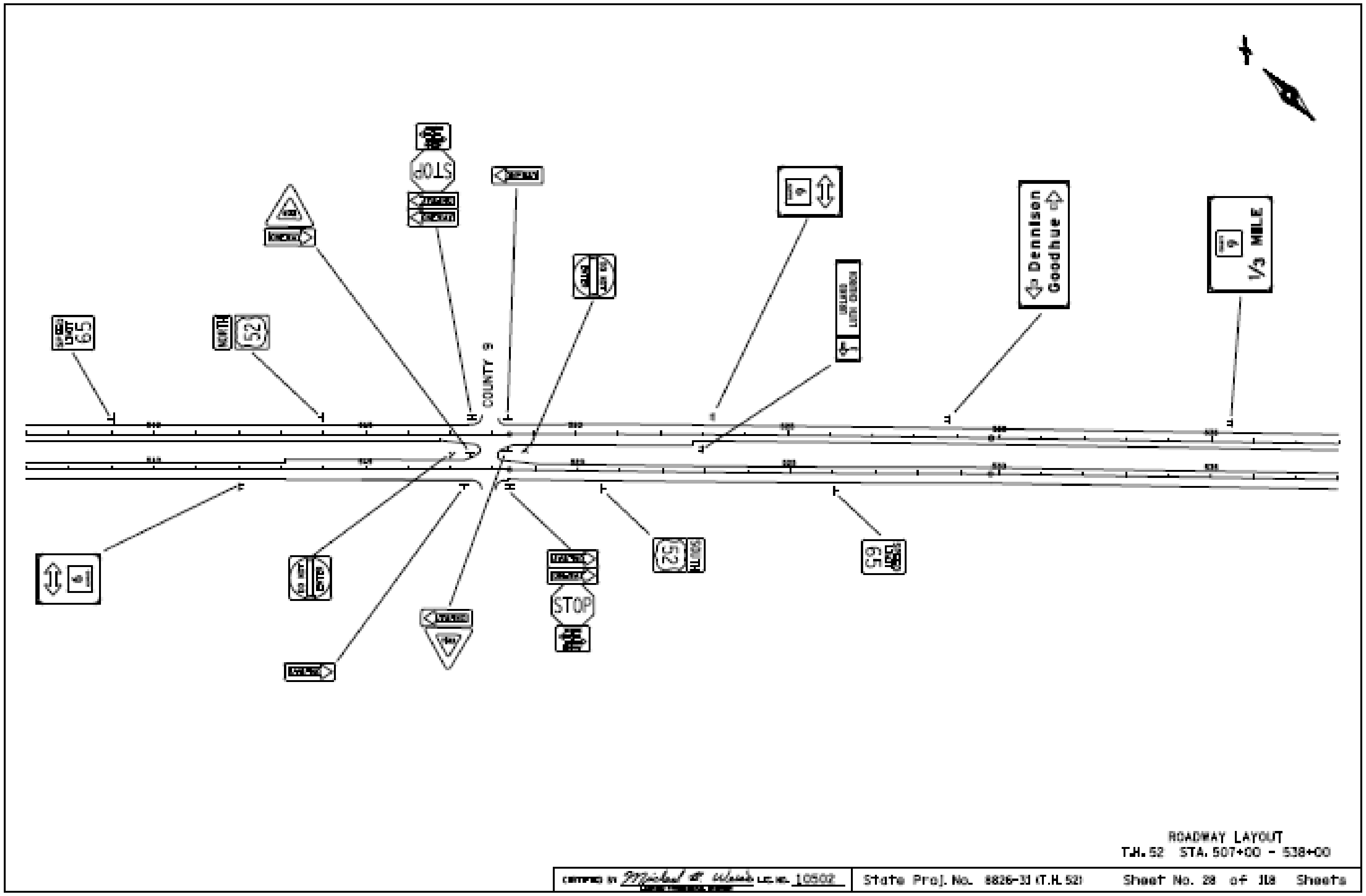
Crashes in rural areas are more severe than in urban areas. Nationally, although most crashes occur in urban areas, more than half of the *fatal* crashes occur in rural areas. Approximately 10% of the all the police-reported crashes each year are stop-sign related. Again, although more than half of the stop-sign related crashes occur in urban areas, over 60% of the fatal crashes occur in rural parts of the country. Fatalities and injuries resulting from stop-sign related crashes cost approximately $28 billion annually.

The purpose of CICAS-SSA is to improve safety at rural intersections by providing a driver with timely, intuitive information designed to assist with either crossing or entering the major road traffic from a minor road.

To illustrate the typical thru-stop intersection that is the focus of CICAS-SSA, Figure 1 shows a Minnesota intersection that has been the subject of research supporting CICAS-SSA. The major road is US52, which runs north-south between Minneapolis/St. Paul and Rochester and has an average daily traffic count of nearly 18,000 at the east-west minor road - CSAH 9. Figure 2 illustrates the current placement of static signs at a typical thru-stop intersection of a high volume, high speed expressway with a low volume, lower speed county road. As a system, the current signing is intended to regulate minor road movements crossing or entering the major road.

Figure 1: Minnesota Intersection – US52 and CSAH 9

Figure 2: Current "System" of Signs (at US52 and CSAH 9)



1.2. Vision and Goals

The vision for CICAS-SSA is wide deployment at rural thru-stop intersections which have significantly high crash rates so as to reduce crashes and severity through improved gap acceptance by drivers. It is envisioned that the initial CICAS-SSA systems will be deployed at intersections with the greatest safety problems and that the systems will be primarily infrastructure-based to provide benefits to all drivers (i.e., both VII-equipped and non-VII equipped vehicles). Information and warnings will be provided via a driver infrastructure interface (DII) (e.g., a dynamic message sign(s)) located at the intersection. In addition, for VII-equipped vehicles, the initial CICAS-SSA systems may provide information and warning timings that are specifically tailored based on information transmitted from the equipped vehicle to the roadside. It is further envisioned that the next incremental advance in CICAS-SSA functionality may be information presented inside the vehicle via a driver vehicle interface (DVI). This could purely be an “in-vehicle signing” capability or possibly a vehicle-generated message based on onboard processing of data provided from the CICAS-SSA infrastructure components. As more and more vehicles become equipped with VII capabilities, the ultimate vision for CICAS-SSA is to be primarily a vehicle-based system supported through vehicle to vehicle communications and in-vehicle DVIs. This would enable ubiquitous CICAS-SSA services and other vehicle collision avoidance services independent of supporting infrastructure components, thus allowing coverage on all roadways and intersections. It is acknowledged that for “gap acceptance related crashes”, a very high market penetration of equipped vehicles is necessary in order to provide these services due to the need to be aware of the location of all vehicular traffic on the roadway.

The Concept of Operations presented in this document, focuses primarily on the initial CICAS-SSA system as described in the vision above. Namely, the system is primarily infrastructure-based, with a DII, but with the capability to tailor information and warning timings based on vehicle to infrastructure communications.

The goal of CICAS-SSA is to provide a cooperative decision support system that will help drivers safely negotiate rural thru-stop intersections. The system will support the minor-road driver in identifying unsafe gaps in major road traffic at the intersection. However, the system will *not* replace drivers’ gap decision-making process; instead, the driver remains responsible for choosing a safe gap and safely crossing the intersection.

1.3. Assumptions and Constraints

There are a number of assumptions and constraints affecting CICAS-SSA. Some of these constraints may also represent functional requirements, which will be specified in the requirements documentation. Furthermore, although several of these assumptions and constraints relate to a DII, similar assumptions and constraints may also be needed for a vehicle based, or Driver Vehicle Interface (DVI), implementation. The following list is numbered for reference only and does not represent a priority order.

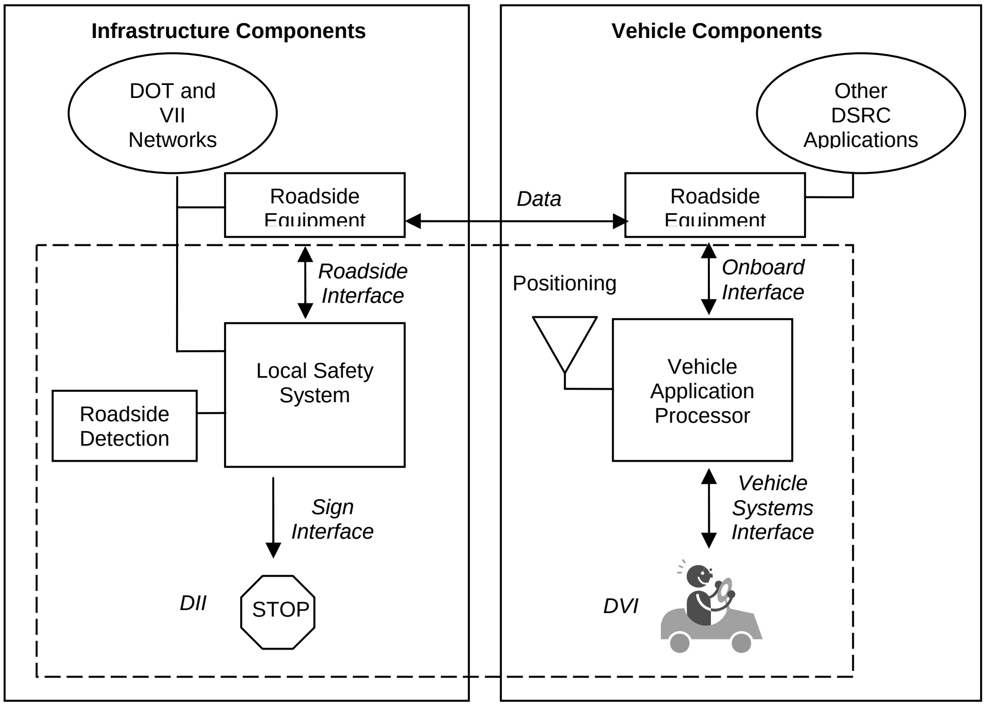
1. **Applies to most thru-stop intersection geometries.** The interface solutions apply to most rural thru-stop intersections regardless of specific geometry. This is important because designing for specific intersection geometries would reduce the extent to which the solutions generalize to other intersections and other states.
2. **Minor road driver is provided assistance.** Regulatory signs at the intersection control traffic flow; the CICAS-SSA system only assists the minor road driver in obeying traffic laws. The interface solutions are targeted toward the minor road driver and it is assumed the minor road driver is responsible for any crash that would occur. Improving the decision making of minor road drivers will therefore reduce the likelihood that the same type of crash occurs.
3. **Minor road driver obeys regulatory signing.** The interface solutions assume the minor road driver stops before proceeding through the intersection. The solutions do not address situations where minor road drivers violate the regulatory signing (willfully or due to inattention). A secondary benefit of some solutions is that the interface could increase the conspicuity of the intersection and reduce the likelihood of unintended regulatory sign violations.
4. **System does not impede traffic on the major road.** The CICAS-SSA system should have minimal adverse effect mainline traffic speeds and volumes. Drivers heeding the advice of the CICAS-SSA system should produce less than a 10% variation in mainline traffic speed. When computing safe sightlines for intersections, a 30% decrease in speed is allowable by AASHTO guidelines. However, 30% speed variations would adversely affect traffic flow on the mainline. Sightline guidelines are found in, "A policy on geometric design of highways and streets (4th ed)", Washington, DC: AASHTO.
5. **Minimal training required.** When possible, the interface solutions use stereotypic coding of information (color, frequency, symbols) to ensure meaning and that required actions are intuitive in order to increase understanding by drivers with minimal exposure and it is hoped this will reduce the need for training.
6. **Minimal additional signage required.** For some of the interface solutions, signage is needed to explain how the system works. To minimize cognitive overload, the number and complexity of the signs will be limited.
7. **Robust to outdoor roadside conditions.** Each interface solution is visible in winter conditions, such as blowing and drifting snow. The interfaces must also withstand plowing and not interfere with plow operations. The system must be visible in direct sun light and withstand all temperature, humidity, vibration and electrical conditions at the roadside.
8. **Visible at night.** The interface solutions are visible at night.
9. **No interference with existing traffic control devices.** The interface solutions complement and not interfere with existing traffic control devices. Obscuring a stop sign by placing a display in front of it would be an example of interfering with an existing traffic control device.
10. **Use a prohibitive frame.** All the interface solutions use a prohibitive framework (e.g., "Do not turn left or cross"). This is important because a permissive framework is more liable if compliance leads to a crash (see Donath and Shankwitz, 2001).

11. **Median monitored for occupancy.** The system can support only one minor road vehicle a time. This requires that the system has a method of identifying which minor road driver is the relevant target. For example, this may require specifying a fixed area at the stop signs that demarcate the assumed location and starting point of the stopped target vehicle. This is necessary to have a fixed basis for calculating movement time in the unsafe lag threshold calculations. In addition, the system will need to (1) monitor and alternate access for cross traffic from the minor road and (2) monitor the occupancy state of the median and prohibit entry if the median is occupied.
12. **Accommodate major road traffic that exits at the minor road.** To the extent that major road traffic exiting to the minor road intersection is considered a relevant or hazardous condition, it will be necessary to identify major road traffic entering the intersection.
13. **Utilize Digital Short Range Communication (DSRC).** As approved by the Federal Communications Commission (FCC), DSRC will provide an ideal medium for transmitting data from V2I and I2V.
14. **Service to all vehicles.** System provides some level of service to both equipped and unequipped vehicles, as well as both passenger and commercial vehicles.
15. **Track every major road gap and lag.** The system is capable of reliably tracking every approaching major road gap and lag.

1.4. System Boundaries

The system boundaries for CICAS-SSA illustrate what is included within and outside the system. Figure 3 illustrates the logical system boundaries for CICAS-SSA. Items inside the dashed line are the focus of this remaining document, and although the items outside the dashed line may relate to CICAS-SSA, they are beyond the scope of this document. Following Figure 3 is an explanation of why each item outside the boundaries has been identified as such.

Figure 3: CICAS-SSA Logical System Boundaries



1.4.1. DOT and VII Networks

The local safety system may generate or receive messages (such as system health and status) from one or more systems outside the system boundaries. Although the messages and interfaces relate to CICAS-SSA, the networks themselves are outside the system boundaries.

1.4.2. Roadside Equipment

The CICAS-SSA message sets, formats and communication requirements are within the system boundaries. However, the standardization, implementation of security protocols and development of the roadside equipment are not.

1.4.3. Other DSRC Applications

CICAS-SSA will be compatible with and operate in conjunction with other applications using the DSRC radio data link. However, modifications to other applications are outside the boundaries of CICAS-SSA.

1.4.4. Legal Boundaries

Enforcement actions and data privacy issues at CICAS-SSA intersections are beyond the scope and boundaries of the CICAS-SSA system.

1.4.5. Government Policy

The CICAS-SSA system will deliver advisory messages through the DII. The messages and infrastructure delivery will need to comply with the Federal Manual on Uniform Traffic Control

Devices. However, the process for modifying – as may be necessary for compliance – the Federal Manual on Uniform Traffic Control Devices is outside the system boundaries.

2. Reference Documents

Several government and non-governmental documents were referenced for this Concept of Operations. Table 1 identifies the relevant materials by title and availability. These documents, of the exact issue shown, form a part of this document to the extent specified. In the event of a conflict in requirements between the referenced documents and the contents of this document, this document shall be considered the superseding requirement.

Table 1: Reference Documents

Document Title (Publication Date)	Document Availability
1. Minnesota Manual on Uniform Traffic Control Devices (May 2005)	Published by Mn/DOT, Office of Traffic, Safety and Operations, 1500 W. County Road B2, Roseville, MN 55113, 651.234.7000 http://www.dot.state.mn.us/trafficeng/otepubl/mutcd/index.html
2. Roadway Layout, State Project No. 8826-31 (T.H. 52) Sheet No. 28 of 118	Published by Mn/DOT, Office of Traffic, Safety and Operations, 1500 W. County Road B2, Roseville, MN 55113, 651.234.7000
3. Infrastructure Consortium Proposal for Intersection Decision Support (2001)	Donath, M., and Shankwitz, C. Published by University of Minnesota, Center for Transportation Studies, 200 Transportation and Safety Building, 511 Washington Avenue SE, Minneapolis, MN 55455, 612.626.1077
4. Review of Minnesota's Rural Intersection Crashes: Methodology for Identifying Intersections for Intersection Decision Support (2004)	Preston, H., Storm, R., Donath, M., and Shankwitz, C. Published by Mn/DOT, Research Services Section, 395 John Ireland Boulevard, St. Paul, MN 55155, 651.366.3780 http://www.research.dot.state.mn.us/detail.asp?productID=1925
5. A Simulator-Based Evaluation of Smart Infrastructure Concepts for Intersection Decision Support for Rural Thru-STOP Intersections (2007)	Laberge, J., Creaser, J., Rakauskas, M., and Ward, N. Published by University of Minnesota, Center for Transportation Studies, 200 Transportation and Safety Building, 511 Washington Avenue SE, Minneapolis, MN 55455, 612.626.1077 http://www.its.umn.edu/Publications/ResearchReports/reportdetail.html?id=1420
6. Design of an Intersection Decision Support (IDS)	Laberge, J.C., Creaser, J.I., Rakauskas, M.E., Ward, N.J.

Interface to Reduce Crashes at Rural Stop-Controlled Intersections; Transportation Research Part C: Emerging Technologies, 14, 39 – 56 (2006)	Published by Elsevier http://www.elsevier.com/wps/find/journaldescription.cws_home/130/description#description
7. Concept Evaluation of Intersection Decision Support (IDS) Systems to Support Drivers' Gap Acceptance Decisions at Rural Stop-Controlled Intersections; Transportation Research Part F: Traffic Psychology, 10, 208 – 228 (2007)	Creaser, J.I., Rakauskas, M.E., Ward, N.J., Laberge, J.C., and Donath, M. Published by Elsevier http://www.elsevier.com/wps/find/journaldescription.authors/600660/description#description
8. ASTM E2213-03 – Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems - 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications	Published by American Society for Testing and Materials (ASTM) International http://www.astm.org
9. IEEE 1455-1999 – Standard for Message Sets for Vehicle/Roadside Communications	Published by the Institute of Electrical and Electronics Engineers (IEEE) http://shop.ieee.org/ieeestore/
10. IEEE 1609.2-2006 – Standard for Wireless Access in Vehicular Environments (WAVE) - Security Services for Applications and Management Messages	Published by the Institute of Electrical and Electronics Engineers (IEEE) http://shop.ieee.org/ieeestore/
11. SAE J2735 – Dedicated Short Range Communications (DSRC)	Published by the Society of Automotive Engineers (SAE) http://store.sae.org

Message Set Dictionary	

3. User-Oriented Operational Description

This section identifies the prospective users of the CICAS-SSA system and provides a non-technical explanation of how each user group will interact with the system once it is operational.

3.1. CICAS-SSA Users and Stakeholders

The CICAS-SSA system is primarily intended for minor road drivers as users, to support their decision making process at thru-stop intersections. Other users and stakeholders associated with the system range from major road drivers to other VII applications. Following is list of the intended users and stakeholders along with an explanation of how they are expected to interact with the system. Figure 4 then illustrates how these groups will interact with the system. It is important to note, however, that as VII and CICAS applications evolve the user interactions depicted in this figure will also change. For example, as more vehicles are equipped with VII components that facilitate in-vehicle warnings, the need for infrastructure based warnings may diminish. However, the anticipated timeframe for this transition will likely be extensive and is difficult to predict. As such, the value of an infrastructure based warning will be evident in the reduction of crash rates that can be recognized while in-vehicle systems continue to evolve.

- **Minor Road Driver.** These users interact most directly with CICAS-SSA. They are the drivers arriving at the intersection from the minor road of a thru-stop intersection. They may turn left or right onto the major road, or they may simply cross the major road. It is also important to note here that CICAS-SSA is intended to provide information to those minor road drivers who stop legally at the intersection. It is not currently designed to address those drivers who violate the stop sign.

- **Major Road Driver.** These users have indirect interaction with the system. However, it is possible that a more direct interaction could be available to the major road driver choosing to make a left turn onto the minor road. If roadside signing is placed on the far side of the road, across from the median, it is conceivable that the major road driver making a left turn could be provided with the same information about far side traffic as the minor road driver.

- **Traffic Control Equipment Manufacturers.** These stakeholders have a direct role in manufacturing infrastructure system components. They may also interact with traffic operations personnel to sell, install, configure and/or maintain the system.

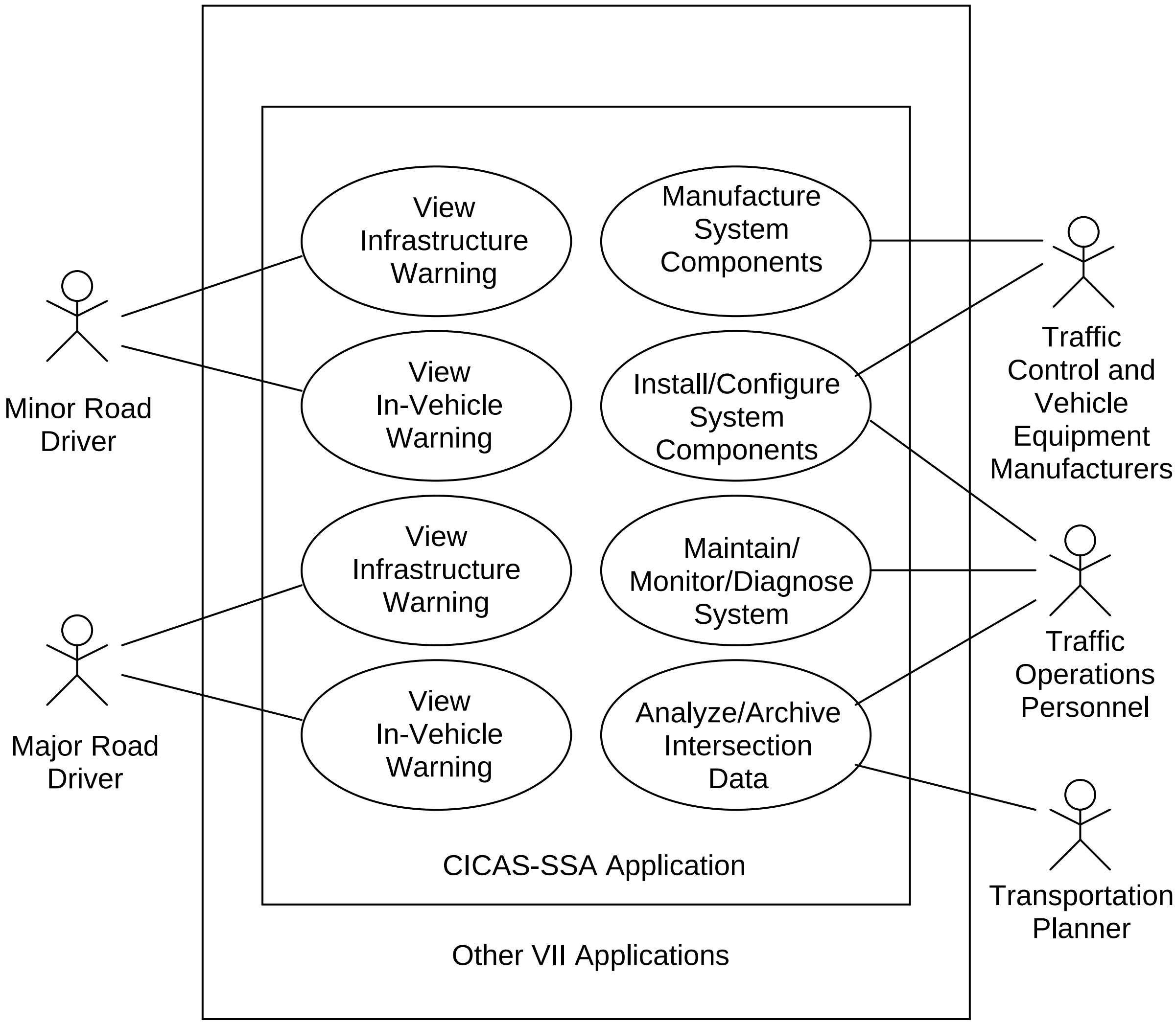
- **Vehicle Equipment Manufacturers.** These stakeholders have a direct role in manufacturing in-vehicle system components such as the Onboard Interface, Vehicle Application Processor, Vehicle Systems Interface and DVI (as referenced in Figure 3).

- **Traffic Operations Personnel.** These users interact with the system through installation, operation and maintenance activities. They may design and oversee installation of the system at an intersection, configure the system, monitor operations, and maintain the system. These users may also interact with another user group – transportation planners – to identify candidate intersections for the system to be installed or to analyze performance data collected from an intersection already equipped with the system.

- **Transportation Planner.** These users will indirectly interact with the system as they may review data collected on speeds and vehicle types in combination with crash data. They may also interact with traffic operations personnel to analyze data for system benefits or to make decisions regarding additional deployments.

- **Other VII Applications.** These users are actually other systems that may interact with CICAS-SSA. VII applications may take speed and vehicle location data collected through CICAS-SSA to perform other safety or traffic related functions.

Figure 4: User/Stakeholder Interaction with CICAS-SSA



4. Operational Needs

This section identifies the operational needs for CICAS-SSA, which also can be used to drive system requirements. Specifically, this describes what the system needs to do. The following needs are numbered for reference only. CICAS-SSA should:

1. Not impede traffic on the major road.
2. Require minimal additional signage and not interfere with existing traffic control devices.
3. Alert minor road drivers of oncoming traffic in time for them to avoid entering the intersection.
4. Monitor the median for occupancy and accommodate major road traffic the exists at the minor road.
5. Use a prohibitive frame.

6. Utilize DSRC for communication from vehicle to infrastructure.
7. Take into account the full range of driver types.
8. Work with all types of vehicles – passenger to commercial.
9. Function in all weather and lighting conditions.
10. Work at most thru-stop intersections.
11. Function for a wide range of intersection geometries.
12. Have an acceptable rate of false alarms and missed alarms when an alarm should have been issued.
13. Use alerts and warnings that are comprehensible to drivers and compatible with MUTCD guidelines.
14. Have a failure mode that restores the intersection to the static, regulatory signing already in place.
15. Have a high degree of reliability and availability.
16. Needs to be backwards compatible with previous versions of the CICAS-SSA system.
17. Must not preclude interoperability and integration with future VII applications and vehicle safety systems.

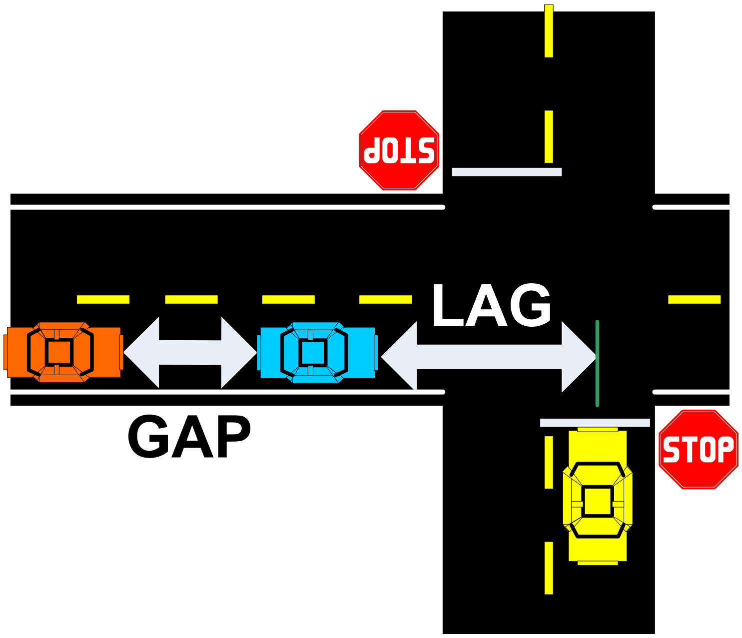
5. System Overview

This section presents an overview of the CICAS-SSA system by describing gaps and lags, the scope, system components and interfaces, and capabilities.

5.1. Gap Definitions

Herein, gap is used as a generic term to represent either the space between vehicles on the major road, or the space between the vehicle on the minor road and a vehicle approaching on the major road. However, to be clear, the primary parameter by which a driver decides to cross or enter mainline traffic is the lag as shown in Figure 5.

Figure 5: Gaps and Lags Perceived by Driver



It is assumed the first available "gap", which is actually the "lag" shown in Figure 5, is the one that is of greatest interest to the minor road driver. The system provides driver support in terms of only the lag defined by the headway of the lead vehicle in the mainline traffic with respect to the center of the minor vehicle lane. Information regarding gaps beyond the lag is not conveyed to the driver on the minor road. However, the system does monitor the gaps as well as the lags along the major road because gaps upstream become lags as major road traffic approaches the minor road, allowing timely information to be presented to the minor road driver as traffic passes by. It is also important to note that "closest" is in terms of time to the intersection, and not a distance between the intersection and oncoming traffic.

5.2. Scope

CICAS-SSA will support the minor-road driver in identifying unsafe gaps in major road traffic at the intersection. However, the system will *not* replace drivers' gap decision-making process; instead, the driver remains responsible for choosing a safe gap and safely crossing the intersection.

In order for the CICAS-SSA to be useful to drivers, the alert and warning information must support the natural process of the negotiation tasks engaged by drivers at this type of intersection. Previous research has analyzed the primary information stages involved in negotiating a stop-controlled intersection. Table 2 (Laberge et al., 2007) describes intersection negotiation from a perceptual and cognitive point of view, as well as behavioral. Tasks are listed in an approximate temporal order, but there may be some overlap between the subtasks.

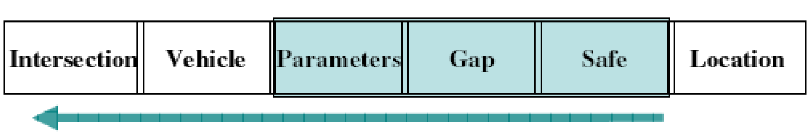
Table 2: Task Analysis for Rural Intersection Negotiation

<table>
<tr><th>Task Goal</th><th>Task</th><th>Sub-Task(s)</th></tr>
<tr><td rowspan="4">Approach intersection</td><td>A. Detect intersection</td><td>A1. Detect intersection features such as signs, signals, pavement markings, and curb edges</td></tr>
<tr><td>B. Decelerate</td><td>B1. Apply brake
B2. Apply adequate braking force</td></tr>
<tr><td>C. Enter correct lane (if required)</td><td>C1. Determine if already in desired lane
C2. If not, scan rearview/side mirrors and/or shoulder for conflicting vehicle
C3. If vehicle present, detect and estimate gap, accept or reject gap, and change lane</td></tr>
<tr><td>D. Signal if intending to turn</td><td>D1. Apply correct signal for intended maneuver (left, right)
D2. Apply signal well in advance of intersection</td></tr>
<tr><td rowspan="4">Assess safety of entering intersection</td><td>E. Detect traffic-control device (signs or signals)</td><td>E1. Detect signs or signals (if present)</td></tr>
<tr><td>F. Interpret traffic-control device</td><td>F1. Understand sign or signal
F2. Be knowledgeable of right-of-way rules
F3. React appropriately and stop or slow down as needed</td></tr>
<tr><td>G. Monitor lead vehicle (if present)</td><td>G1. Observe path of lead vehicle and anticipate stops
G2. Estimate speed, distance, gap
G3. Adjust headway as needed</td></tr>
<tr><td>H. Detect traffic and pedestrians</td><td>H1. Detect traffic and/or pedestrians
H2. Yield as required</td></tr>
</table>

Task Goal	**Task**	**Sub-Task(s)**
	I. Detect, evaluate, and monitor gaps in traffic	I1. Detect gap I2. Estimate speed, distance, arrival time I3. Perceive gap size I4. Evaluate whether gap is acceptable I5. Monitor changes in gap size
Traverse intersection	J. Accept gap and complete maneuver	J1. Determine when to initiate maneuver J2. Check pathway for obstructions J3. Yield and adjust velocity as required J4. If turning, turn steering wheel, accelerate, and adjust speed to traffic J5. If straight, accelerate
	K. Continue to monitor traffic and control device until intersection is cleared	K1. Monitor traffic, pedestrians, or lights K2. Anticipate light changes (if relevant) and sudden stops, accelerations, or violations by other traffic K3. Yield or slow down as required

These information stages are presumed to be engaged by drivers in a logical sequence as shown in Figure 6. Accordingly, the temporal sequence of information acquisition required to support the intersection negotiation task is presumed to be hierarchical. For example, drivers must be aware that an intersection exists in order to trigger them to search for the presence of vehicles approaching that intersection. Similarly, the decision that a gap is safe or unsafe is predicated on detecting a gap by observing parameters related to the approaching traffic, such as speed, distance from intersection or size of approaching vehicle.

Figure 6: Information Hierarchy



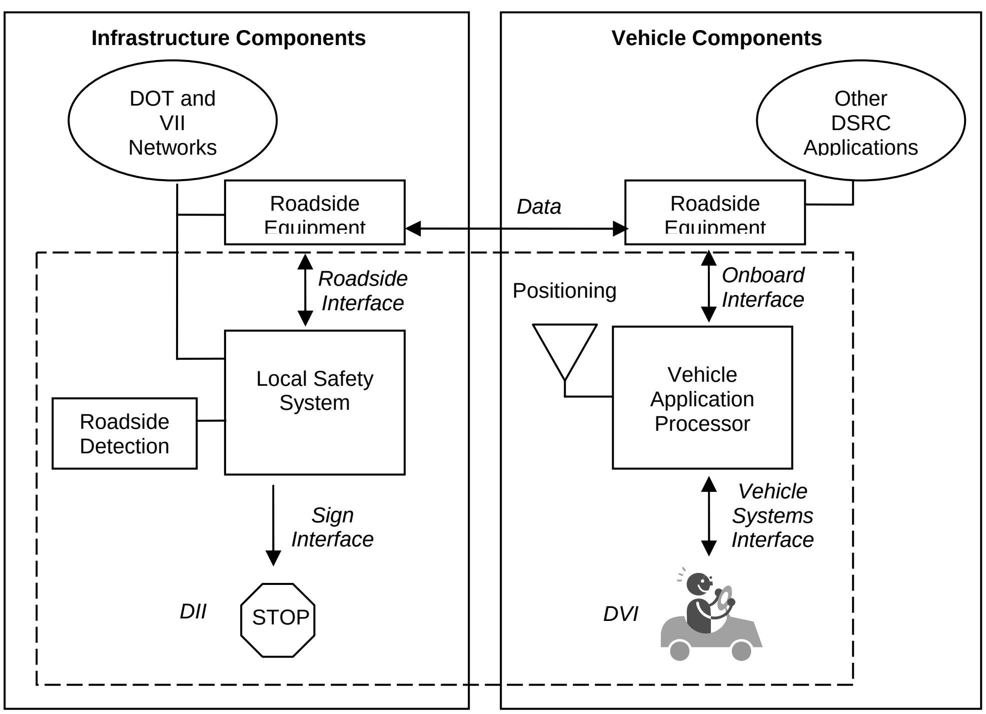
Note that an intersection crash may result from a mistake at any stage in this information hierarchy. Indeed, it is not possible to predict at which stage a mistake may occur. Thus, it is reasonable to try to support higher information levels with the CICAS-SSA system. This goal is achieved by presenting information that supports driver perception of vehicle parameters, gap size, and unsafe gap thresholds. Presenting information at higher levels must then logically support the lower-level information stages – detection of vehicles and the intersection – upon which it is based.

The form of support will be based on displaying information to the driver using a sign or in-vehicle display at the intersection. This information will relate to an estimation of the unsafe lag threshold based on relevant parameters associated with each particular crossing minor road driver. The driver interface will contain information elements that will present one or more of the following types of information: hazard detected, lag time, prohibited maneuvers. The role of the driver is to consider this information and decide on the appropriate course of action. These relevant parameters will constitute a basic message set that will be conveyed between the approaching minor road vehicles and the CICAS-SSA system that generates the support information to be presented via a driver interface.

5.3. System Components and Interfaces

Figure 7 presents a high-level overview of the CICAS-SSA system. It provides a reference for describing operations and also introduces the system components and interfaces. The overview is illustrated in terms of both infrastructure and vehicle components.

Figure 7: CICAS-SSA Components and Interfaces



As depicted in Figure 7, there are several components – infrastructure and vehicle – to this system. Following is a more detailed explanation of the individual components and the interfaces between them.

- **Roadside Detection.** Detecting vehicle presence is necessary for both the major and minor road. This component may consist of any detection product (i.e., inductive loops, radar, lidar, cameras, etc.) that reports location, speed and vehicle type. These data points are essential to the algorithm used to determine unsafe gaps and when the system should transmit a warning. It is important to note that there are three separate roadside detection subsystems: the mainline subsystem, the minor road subsystem, and the median subsystem. The major road subsystem determines vehicle presence, speed, and lane of travel. The minor road subsystem determines vehicle classification (based on size), and position. The median subsystem determines the presence of vehicles waiting in the median.

- **Local Safety System.** This is the CICAS-SSA computer that will accept roadside detection data, run the algorithm, prepare the gap warning, and activate the DII.

- **Roadside Interface.** This interface will allow communication between the DSRC radio and the roadside application processor.

- **Sign Interface.** This interface will facilitate transfer of the gap warning to the DII from the roadside application processor.

- **Driver Infrastructure Interface (DII).** This component will consist of a changeable message sign used to relate to an estimation of the unsafe lag threshold based on relevant parameters associated with each particular crossing minor road driver.

- **Onboard Interface.** This is the interface between the CICAS-SSA application running in the vehicle and the DSRC radio that relays messages to and from the infrastructure components.

- **Vehicle Application Processor.** This is the point at which the CICAS-SSA application may be run within the vehicle to run the algorithm, prepare and then deliver the gap warning to activate a DVI.

- **Vehicle Systems Interface.** This interface will allow transfer of the gap warning or data between the vehicle application processor and the DVI. It will also enable the determination of vehicle dynamic data, position and other vehicle data that can lead to better information in the state map or tailored warnings for the driver.

- **Driver Vehicle Interface (DVI).** In addition to the DII, a DVI will consist of an in-vehicle sign that conveys the gap warning to the driver. The DVI may include audible, visual and haptic alerts.

5.4. Capabilities

Each of the CICAS-SSA system components have specific capabilities, or functions, that contribute to the overall system performance. This section explains each component's capabilities in relation to the system as a whole.

- **Roadside Detection.** The roadside detection system consists of three distinct subsystems: the mainline subsystem, the minor road subsystem, and the median subsystem. The major road subsystem determines vehicle presence, speed, and lane of travel. The minor road subsystem determines vehicle classification (based on size), and position. The median subsystem determines the presence of vehicles waiting in the median.

  All three subsystems play a role in the execution of driver alerts and warnings. The median presence detection system monitors the occupancy of the median crossroads. If a vehicle is detected to be in the crossroads, the system will indicate to the driver on the minor road that it is unsafe to cross the traffic stream. This approach avoids both crossing path conflicts (the vehicle in the median facing the vehicle on the minor road) and occupancy conflicts (the vehicle on the minor road not having space in the median because another vehicle is present). A primary factor in unsafe gap detection is the size of the vehicle waiting on the minor road; longer vehicles require larger lags to safely cross or enter mainline traffic. The minor road sensor suite must determine vehicle presence, size, and position in order to accurately and reliably warn drivers of unsafe lags. Without a vehicle classification capability, alerts and warnings provided by the system would likely be considered too conservative or unbelievable by a majority of the drivers exposed to the system.

  The mainline sensor subsystem is responsible for determining the present state of the intersection in terms of gaps and lags. The mainline sensor system computes the presence, position, and speed of each vehicle within its coverage zone, and from that determines the lags and gaps available to the driver on the minor road. This gap/lag information, combined with vehicle classification and driver information (via the DSRC radio, see below), enables the roadside unit to compute when conditions are unsafe for that minor road driver. When unsafe conditions are detected, the driver is warned via either the DII or DVI.

- **Roadside Equipment.** The roadside equipment enables the cooperative element of the CICAS-SSA system, and enables a variety of system architectures. The least complex implementation has the vehicle sending relevant vehicle and driver information (i.e., vehicle type, driver age, preferred lag length) to the roadside unit computing alerts and warnings, thereby optimizing the system performance for a particular driver. The architecture also allows for the roadside equipment to provide intersection state map data

to the vehicle; the vehicle on-board unit uses the dynamic state map information and its own algorithm to compute the alert and warning status for the intersection. If the vehicle "knows" driver preferences, the alerts can be optimized at a high level for a particular driver.

- **Local Safety System**. The local safety system collects all sensor information (mainline sensor suite, minor road sensor suite, and median crossroads sensor suite) data and computes the dynamic state of the intersection. This is done presently at a rate of 10 Hz. Depending on system architecture, this dynamic state data can be used by either the roadside unit or the vehicle on-board unit to assess the threat to the minor road driver and to issue warnings and alerts. The processor may be equipped with local data storage devices or network connections to allow time histories or crash/near crash events to be captured for further analysis.

- **Driver Infrastructure Interface (DII)**. The DII will take the form of a variable message sign, and provide information to drivers to indicate when conditions are unsafe to cross or enter the mainline traffic. The timing and content of the DII is controlled by the roadside unit. Timing of the alerts and warnings presented on the DII can be adjusted based on the information received from a vehicle on the minor road equipped with a DSRC radio.

- **Driver Vehicle Interface (DVI).** The DVI will be located in the vehicle, and will provide information indicating an unsafe condition to a driver located on the minor road. In one realization, information passed from the vehicle to the roadside unit would be used to modify the alert and warning timing, and the roadside unit would then broadcast the appropriate alert or warning message to the vehicle, which would then activate the DVI. In another realization, the roadside unit would continuously broadcast dynamic intersection state data, and the on-board unit would use this dynamic state information to execute its threat assessment algorithm, and activate the DVI at the appropriate time.

- **Vehicle Application Processor.** The vehicle application processor may use dynamic state map information provided via the roadside equipment from the roadside application processor to assess threats, and compute alert and warning conditions. In contrast, the threat and corresponding alert and warning conditions could be computed by the local safety system and delivered to the vehicle as an in-vehicle signing message.

6. Operational and Support Environments

This section describes the physical operational and support environments for CICAS-SSA. The environments are described according to the facilities, equipment, management system hardware and software, and operations activities needed to operate the system.

6.1. Facilities

The CICAS-SSA has been developed to address crashes at rural thru-stop controlled intersections. The facilities related to this type of system primarily consist of an intersection between a minor and major road. The major roads typically fall under control of the state DOT,

and the minor roads are typically county or township owned. Jurisdictional cooperation is required to deploy such a system because detection, transmission, signing and electrical components will likely be located in the rights of way of both jurisdictions. The operation of the CICAS-SSA system is also generally insensitive to roadway geometry. However, complicated geometries will add to system complexity in that additional sensors are needed to provide coverage over both vertical and horizontal curves.

In addition to the physical roadway, local utilities are another facility that must be considered for a CICAS-SSA system. Not unlike a conventional traffic control signal, CICAS-SSA will need a source of electrical power at the roadside. Utility access should, however, be a lesser concern because power is commonly adjacent to roads where the CICAS-SSA is needed.

The only other facilities that may be affected by the deployment of a CICAS-SSA system are transportation operations centers or traffic engineering offices where other traffic control devices may be managed by traffic operations personnel. These facilities may be used for remote monitoring and diagnostics or gathering and archiving data.

6.2. Equipment and Software

Following is a list of physical equipment and software associated with the CICAS-SSA system. Each item is presented according to its physical location within the system, which may include the roadside, vehicle or a transportation facility.

Roadside Detection – Major Road

- Sensors capable of providing range, range rate, and azimuth angle information to targets traveling on the mainline
- Wired or wireless communication equipment to deliver sensor information to the application processor
- Power

Roadside Detection – Minor Road

- Vehicle size (length, height) sensing system
- Vehicle presence and position sensor
- Power
- Wired or wireless communication to deliver sensor information to application processor

Roadside Detection – Median

- Vehicle presence sensor
- Power
- Wired or wireless communication equipment to deliver information to the application processor

Roadside Equipment

- DSRC radio

Local Safety System
- Rugged computer
- Power
- Communication channels from major road, minor road and median sensors
- Interface to DII
- Traffic-grade cabinet
- Antenna

Local Safety System Software
- Secure, real-time operating system to run the application and communication interfaces
- DSRC radio communication software
- CICAS-SSA application software
- Security/authentication software
- Diagnostics
- Network communication software

Vehicle Application Processor
- Onboard unit
- Power
- Interface to DVI
- Antenna

Vehicle Application Software
- Secure, real-time operating system to run the application and communication interfaces
- DSRC radio communication software
- CICAS-SSA application software
- Security/authentication software
- Diagnostics

Driver Infrastructure Interface (DII)
- Dynamic, variable message sign
- Power
- Communication from application processor

Driver Vehicle Interface (DVI)
- Speaker (for audio), screen (for video) or vibration mechanism (for haptic)
- Power
- Communication from application processor

6.3. Operations Activities

Operations activities include daily operations, planning and performance measurement, and manufacturing of system components. This section explains each of these activities in relation to the CICAS-SSA users/stakeholders who participate in or oversee them.

6.3.1. Daily Operations

Traffic operations personnel are the primary users who will oversee daily operations of the CICAS-SSA system. They will monitor and maintain system operation. Monitoring the system may take place via field visits or DOT networks to ensure the system is operating with specified parameters, to gather data from the system for analysis, or to identify potential maintenance needs. Maintenance may involve replacement of components or interfaces if damage or failures occur. It may also include system upgrades as they become available.

6.3.2. Planning and Performance Measurement

Transportation planners may work with traffic operations personnel to use data gathered from the CICAS-SSA system for broader planning activities. They may also use system data, in combination with crash reports, to measure effectiveness of CICAS-SSA at reducing crashes.

6.3.3. System Component Manufacturing

Traffic control and vehicle equipment manufacturers will produce or integrate system equipment such as roadside detection, application processors, and the DII and DVI. They will interact with traffic operations personnel to design, install and, as desired, operate and maintain the CICAS-SSA system.

7. Operational Scenarios

There are three modes of operation for the CICAS-SSA system – normal, failure and diagnostic.

7.1. Normal Operation

System is working with normal capability such that information is presented on the variable message sign. The only drivers affected by the CICAS-SSA system are those stopped at the intersection with the intent to either enter or cross the mainline traffic. In this situation, to inform the driver on the minor road that the system is active, the DII will be designed with the capability to indicate to a driver on the minor road that the system is active. For instance, a message to the effect to “take caution” when other icons indicating unsafe conditions are not appropriate will indicate to a driver that the system is active as well as reinforcing the need to use caution while at the intersection.

When unsafe conditions are detected, the “take caution” icon will be replaced with an appropriate alert or warning. Should the driver accept the advice offered, unsafe conditions will be avoided.

Depending on final system architecture and the cooperative capabilities of vehicles interacting with CICAS-SSA, four different normal operational scenarios could be realized with the system. These four scenarios are described below.

- **Non-cooperative system.** With initial deployment, this is the operational scenario most likely to occur. In this case, a non-equipped vehicle approaches the intersection. The minor road sensing system detects the presence of this vehicle, and the CICAS-SSA system will activate the minor road DII alert and warnings at the appropriate time. Once the minor road vehicle clears the minor road, the DII is deactivated so as to not affect mainline traffic. If the minor road vehicle enters the median, the median presence detector will indicate that the median DII should be active so as to support the movement of the vehicle from the median.

- **VII-capable vehicle without DVI.** In this situation, as the VII-equipped vehicle approaches the intersection, this vehicle announces its presence to the roadside equipment. When the roadside equipment acknowledges its presence, the VII-capable vehicle broadcasts to the roadside equipment relevant parameters, which could include preferred alert and warning timing, vehicle mass, length, and classification, performance capabilities, etc. The roadside equipment will utilize that information to optimize the alert and warning timing for that equipped vehicle. At the minor road, the minor road DII provides minor road alerts and warnings. After the minor road vehicle clears the minor road, the minor road DII will be inactivated so that major road traffic won't be affected by stray lighting. If the minor road vehicle enters the median, median sensing will indicate that the median DII should be activated. Once the median vehicle clears the median, the median DII will be inactivated until it is needed again.

- **VII-capable vehicle with DVI – Roadside computed alerts and warnings.** In this situation, as the VII-equipped vehicle approaches the intersection, this vehicle announces its presence to the roadside equipment. When the roadside equipment acknowledges its presence, the VII-capable vehicle broadcasts to the roadside equipment relevant parameters, which could include preferred alert and warning timing, vehicle mass, length, and classification, performance capabilities, etc. The roadside equipment will utilize that information to optimize the alert and warning timing for that VII-capable vehicle. The roadside equipment will monitor the state of the intersection, and at the appropriate time, broadcast alerts and warnings to the VII-capable vehicle. The vehicle application processor will accept the alert and warning messages, and activate the DVI alerts and warnings at the appropriate time. If the vehicle clears the mainline and enters the median, median sensing will indicate its presence, and will broadcast alerts and warnings appropriate for the median location. Again, the vehicle application processor will interpret the alerts and warnings, and will activate the DVI appropriately.

  To avoid DII/DVI conflicts, if a VII-capable, DVI-equipped vehicle requests intersection data, the roadside equipment will inactivate the DII, leaving only the DVI to present alerts and warnings.

- **VII-capable vehicle with DVI – On-board computed alerts and warnings.** In this situation, a VII-capable vehicle equipped with a DVI and vehicle application processor will use dynamic state map data to compute its own alert and warning timing, and control its own DVI. The approaching minor road vehicle will initiate communication to the roadside

equipment, and the roadside equipment will provide intersection state map data to that vehicle at a 10 Hz rate. The vehicle application processor will use this intersection state map data to compute threat assessments and to initiate alerts and warnings on the DVI. Once the VII-capable, DVI-equipped minor road vehicle requests intersection state map data, the roadside equipment will inactivate the DII as to avoid conflicts with the on-board DVI.

7.2. Failure and Diagnostic Modes

If a failure renders the system ineffective or inaccurate at presenting proper alerts and warnings to driver, the system will enter a failure mode. Failures can come from any of the CICAS-SSA components. It should be noted that the DII will be equipped with a “When Flashing, System Inoperative” indicator. This indicator will be an LED flasher with battery back-up which is controlled by the roadside equipment. Should a failure which limits DII effectiveness be detected by the system controller, the “DII Inactive” warning will be activated. Should power to the DII be lost, the battery backup system will sense that as well, and the “DII Inactive” warning will be activated. Battery power will allow the “DII Inactive” flasher to operate even during power outages.

Should the CICAS-SSA system be connected to a traffic operations center, the center will be notified of a system failure. If no connection is available, local law enforcement passing through the intersection can notify the transportation agency of a system failure so a repair crew can be dispatched.

As with any system, occasional failures occur, and to rectify the situation, a diagnostic session is likely needed to trace and correct the problem. Should system diagnoses be required, the DIIs should be covered to avoid the transmission of any incorrect messages to the drivers on the minor road. The bag can be equipped with an “out of service” tag to indicate to drivers on the minor road that the system is not in service. This should avoid any confusion on the part of a driver on the minor road regarding the status of the CICAS-SSA system.

As the system operates, self-diagnostics run continuously. Tables 3-7 focus on the five main system components: roadside detection-major road, roadside detection-minor road, roadside detection-median, local safety system, and DII. For each of these components, the corresponding table presents failures and diagnostics, as well as the anticipated effect on the driver. Should a failure be detected, the system will enter a failure mode, which depending on the severity of the failure, may still allow full or partial operation of the system on one or both minor road intersection approaches.

Table 3: Roadside Detection-Major Road Diagnostic and Failure Mode Causes and Effects

Cause	Crash damages sensor	Power failure	Communication Failure	Bad Sensor
Extent	Single sensor most likely.	Single sensor to entire mainline subsystem (both legs of the mainline).	Single sensor to entire mainline system.	Single sensor most likely.
Diagnostic	No communication from sensors, which issue frequent and periodic status and data messages.	No communication from sensors, which issue frequent and periodic status and data messages.	No communication from sensors, which issue frequent and periodic status and data messages.	Broadcast of sensor error codes; no communication from sensor; sporadic data flow (good sensors send frequent, periodic data packets at all times). A failure would also be indicated if the presence of main line vehicles were not indicated for a longer than expected duration.
Effect on End User	With "overlapping" sensor "beam" design, the trajectory tracking algorithm can continue to operate, resulting in no loss of functionality. Sparser sensor architecture may cause the DII corresponding to that intersection leg to be	For a single sensor power failure, the system might work fine if an overlapping sensor beam architecture is used. If an entire leg suffers a power outage, the DII for that leg will shut down, and the "DII Inoperative" warning will flash.	For a single sensor communication failure, the system might work fine if an overlapping sensor beam architecture is used. If an entire leg suffers a communication failure, the DII for that leg will shut down, and the "DII Inoperative" warning will	For a single sensor failure, the system might work fine if an overlapping sensor beam architecture is used. If an entire leg suffers a catastrophic sensing failure, the DII for that leg will shut down, and the "DII Inoperative" warning will

Cause	Crash damages sensor	Power failure	Communication Failure	Bad Sensor
	inoperative. If the DII is inoperative, the "DII Inoperative" warning will flash.		flash.	flash.

Table 4: Roadside Detection-Minor Road Diagnostic and Failure Mode Causes and Effects

Cause	Crash damages sensor	Power failure	Communication Failure	Bad Sensor
Extent	One or more minor road sensors are lost.	Single sensor to entire minor road subsystem.	Single sensor in the suite to all sensors on a single minor road approach to all sensors on both minor road approaches.	Single sensor most likely.
Diagnostic	No communication from sensors, which issue frequent and periodic status and data messages.	No communication from sensors, which issue frequent and periodic status and data messages.	No communication from sensors, which issue frequent and periodic status and data messages.	Broadcast of sensor error codes; no communication from sensor; sporadic data flow (good sensors send frequent, periodic data packets at all times). A failure would also be indicated if the presence of minor road vehicles were not indicated for a longer than expected duration.

Cause	Crash damages sensor	Power failure	Communication Failure	Bad Sensor
Effect on End User	If the presence of a vehicle on the minor road can still be detected, the alert and warning timing will revert to a default value. If the presence of a minor road vehicle can no longer be detected, and the "DII Inoperative" warning will flash.	If the presence of a vehicle on the minor road can still be detected, the alert and warning timing will revert to a default value. If the presence of a minor road vehicle can no longer be detected, then the "DII Inoperative" warning will flash.	If a single sensor suffers a communication failure, the remaining sensors can still indicate presence of a vehicle. In that case, default alert and warning timing will be issued. If the entire minor road communication system is affected, vehicle presence won't be detected, and the DII will not be activated. If no vehicles are detected for a long period of time, the "DII Inoperative" warning will flash.	If a single sensor suffers a communication failure, the remaining sensors can still indicate presence of a vehicle. In that case, default alert and warning timing will be issued.

Table 5: Roadside Detection-Median Diagnostic and Failure Mode Causes and Effects

Cause	Crash damages sensor	Power failure	Communication Failure	Bad Sensor
Extent	One or more minor road sensors are lost.	Single sensor to entire median component.	Single sensor in the suite to all median sensors.	Single sensor most likely.

Cause	Crash damages sensor	Power failure	Communication Failure	Bad Sensor
Diagnostic	No communication from sensors. Depending on sensor choice, the sensor may issue frequent and periodic status and data messages which can be monitored.	No communication from sensors. Depending on sensor choice, the sensor may issue frequent and periodic status and data messages which can be monitored.	No communication from sensors, which issue frequent and periodic status and data messages. A failure would also be indicated if the presence of vehicles in the median were not indicated for a longer than expected duration.	Broadcast of sensor error codes; no communication from sensor; sporadic data flow (good sensors send frequent, periodic data packets at all times).
Effect on End User	With no median sensor redundancy, there is no means to detect a vehicle in the median. The system alert and warning timing issues warnings consistent with right-of-way rules. To avoid conflicts, if median sensor in determined to be unreliable or is unavailable, the "DII Inoperative" indicator will be activated.	If the presence of a vehicle in the median can't be detected, the "DII Inoperative" indicator will be activated to avoid any potential conflicts with minor road vehicles.	If the presence of a vehicle in the median can't be relayed to the system controller, the "DII Inoperative" indicator will be activated to avoid any potential conflicts with minor road vehicles.	If the presence of a vehicle in the median can't be relayed to the system controller, the "DII Inoperative" indicator will be activated to avoid any potential conflicts with minor road vehicles.

Table 6: Local Safety System Diagnostic and Failure Mode Causes and Effects

Cause	Crash damages cabinet	Power failure	Communication Failure	Computer Failure
Extent	Can range from cosmetic damage to total destruction.	Temporary outage (storms) to complete loss of power (cut line, bad transformer, etc.).	Communication lines to cabinet fail or cut. Local DSL modem or DSL modem rack fails. (Optional: bad DSL modem connection back to a transportation operations center, if so provided.)	Any number of components could fail: power supplies, Ethernet controllers, motherboard, flash memory, etc. Any of these component failures would disable the system controller.
Diagnostic	If the system is connected to a transportation operations center, periodic system status messages would normally be sent. If those messages are no longer sent, a problem with the roadside equipment is likely.	If the system is connected to a transportation operations center, periodic system status messages would normally be sent. If those messages are no longer sent, a problem with the roadside equipment is likely.	If the system is connected to a transportation operations center, periodic system status messages would normally be sent. If those messages are no longer sent, a problem with the roadside equipment is likely.	If the system is connected to a transportation operations center, periodic system status messages would normally be sent. If those messages are no longer sent, a problem with the RSE is likely.
Effect on End User	If crash damage is minor, no affect on user. If connection to sensors and/or DII is damages, it is unlikely that DII could be activated. The "DII Inoperative" warning on the DII may be activated if the DII handshake is lost.	If crash damage is minor, no affect on user. If connection to sensors and/or DII is damages, it is unlikely that DII could be activated. The "DII Inoperative" warning on the DII may be activated if the DII handshake is lost.	If crash damage is minor, no affect on user. If connection to sensors and/or DII is damages, it is unlikely that DII could be activated. The "DII Inoperative" warning on the DII may be activated if the DII handshake is lost.	If crash damage is minor, no affect on user. If connection to sensors and/or DII is damages, it is unlikely that DII could be activated. The "DII Inoperative" warning on the DII may be activated if the DII handshake is lost.

Table 7: DII Diagnostic and Failure Mode Causes and Effects

Cause	Crash damages DII	Power failure	Communication Failure	Display Failure
Diagnostic	Drivers see an inactive DII, RSE receives no communication acknowledgements from the DII.	Driver sees an inactive DII, RSE receives no communication acknowledgements or status information from DII.	RSE receives no communication acknowledgements or status information from DII.	Driver sees an inactive DII, inactive DII segments, or RSE receives no communication acknowledgements or status information from DII. The DII will have diagnostic channels (voltage measurements to illumination blocks to sense activation) and communcation handshaking. IF those fail, the RSE will be able to detect a failure. unlikey to fail during the course of the deployment.
Effect on End User	Partial or total DII failure. If DII is damage (see "Display Failure" column, it may be sensed, and subsequently reported.	Driver sees an inactive DII.	Driver sees an inactive DII. Depending on the source and time of the failure, the driver may see a partially active or partially illuminated DII.	User effect can range from a completely inactive DII to segments which may not illuminate. If a communication, power, or display failure can be detected by the RSE, then the system controller can disable the

				DII, and activate the "system failure" alert associated with the DII.

Appendix A: List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
CICAS	Cooperative Intersection Collision Avoidance Systems
CICAS-CBAT	Cooperative Intersection Collision Avoidance Systems-Cost Benefit Analysis Tool
CICAS-SLTA	Cooperative Intersection Collision Avoidance Systems-Signalized Left Turn Assist
CICAS-SSA	Cooperative Intersection Collision Avoidance Systems-Stop Sign Assist
CICAS-V	Cooperative Intersection Collision Avoidance Systems-Violations
DII	Driver Infrastructure Interface
DSRC	Digital Short Range Communication
DVI	Driver Vehicle Interface
FCC	Federal Communications Commission
I2V	Infrastructure to Vehicle
IDS	Intersection Decision Support
Mn/DOT	Minnesota Department of Transportation
MUTCD	Manual on Uniform Traffic Control Devices
USDOT	United State Department of Transportation
V2I	Vehicle to Infrastructure
VII	Vehicle Infrastructure Integration
WAVE	Wireless Access in Vehicular Environment