Guidebook

Smart Work Zone (SWZ)

Design and Operation

DRAFT

Version 0.1

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Acronyms and Definitions

ADS .... Automated Driving System
ARC-IT .... Architecture Referenced for Connected and Intelligent Transportation
C-V2X .... Cellular Vehicle to Everything
ConOps .... Concept of Operations
CAV .... Connected and Automated Vehicle
dB .... Decibel
DevSpecs .... Developmental Specifications
DIW .... Dynamic Intrusion Detection and Warning
DLM .... Dynamic Lane Merge
DQW .... Dynamic Queue Detection and Warning
DSH .... Dynamic Speed Harmonization
FHWA .... Federal Highway Administration
FDOT .... Florida Department of Transportation
FDM .... FDOT Design Manual
GPS .... Global Positioning System
ITS .... Intelligent Transportation Systems
LED .... Light-Emitting Diode
MPH .... Miles per Hour
PCMS .... Portable Changeable Message Sign
PSEMP .... Project Systems Engineering Plan
PIP .... Public Information Plan
RTMC .... Regional Transportation Management Center
RSU .... Roadside Unit
SWZ .... Smart Work Zone
TTC .... Temporary Traffic Control
TTCP .... Temporary Traffic Control Plan
VSL .... Variable Speed Limit
WZDx .... Work Zone Data Exchange

Chapter 1: Introduction

1.1 Purpose of the Smart Work Zone Guidebook

This Guidebook on Smart Work Zone (SWZ) Design and Operation provides criteria and guidance for the selection, design, and operations of SWZ strategies, systems, and technologies to improve traffic safety, worker safety, and traffic efficiency approaching and within work zones. The guidebook supports Florida Department of Transportation (FDOT) overall improving safety and enhancing mobility goals. Specifically, this guidebook complements FDOT's Strategic Highway Safety Plan, Transportation Systems Management and Operations (TSM&O) Strategic Plan, and Connected and Automated Vehicle (CAV) Business Plan. The Guidebook is in recognition that the Florida Department of Transportation (FDOT) is simultaneously developing Developmental Specifications (DevSpecs), FDOT Design Manual (FDM) Developmental Design Criteria (DDC), and Developmental Standard Plans to describe SWZ technologies and strategies that are intended to actively manage safety and traffic approaching and through work zones.

1.2 Characteristics of Smart Work Zones

SWZ have the following general characteristics:

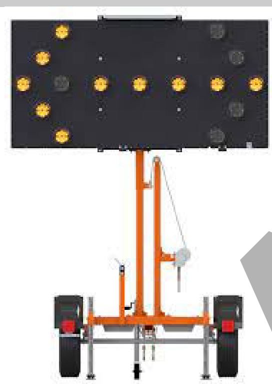
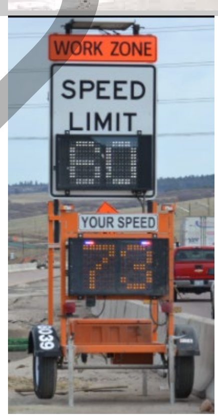
- ***Real-time:*** The system obtains and analyzes traffic flow data in real-time, providing frequently updated information to motorists.
- ***Portable:*** The system is portable, allowing its installation at different locations (with configuration modifications, as necessary).
- ***Automated:*** The system operates in an automated manner with minimal human supervision.
- ***Reliable:*** The system provides accurate and reliable information, keeping in mind the serious consequences of misinforming motorists in work zone situations.

1.3 Smart Work Zone Technologies

SWZs are used to augment and enhance traditional work zone schemes. It is important to always comply with the ***Manual on Uniform Traffic Control Devices*** and the ***FDOT Standard Specifications for Road and Bridge Construction*** when selecting SWZ technologies to use on a project. ***Specifications Dev102SWZ and Dev990SWZ*** provide specifications for technologies that support SWZ strategies.

SWZs use a variety of ITS technologies. Table 1 provides a list of SWZ technologies along with a visual representation of the associated device used for reference.

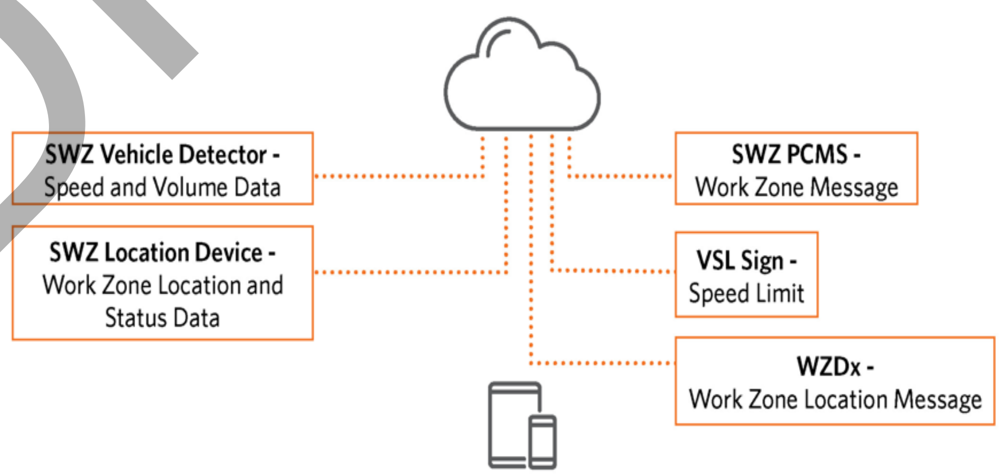
Table 1: SWZ Technologies

Device Name	Visual Representation
SWZ Location Devices	 
SWZ Arrow Board	
SWZ Portable Changeable Message Sign (PCMS)	
Portable Variable Speed Limit (VSL) Sign with Electronic Speed Feedback Sign (ESFS)	

SWZ Vehicle Detector

Portable Advanced Work Zone Information System (AWZI)

SWZ Central Processor



1.4 Smart Work Zone Strategies and Systems

SWZs use combinations of the above technologies to create strategies or systems in response to work zone traffic impact scenarios. SWZ strategies covered in the Guidebook include:

- Work Zone Data Exchange (WZDx) SWZ Location Devices
- Dynamic End of Queue/Slow Speed Warning (DQW)
- Dynamic Lane Merge (DLM)
- Dynamic Speed Harmonization (DSH)
- Work Zone Intrusion Detection and Warning (DIW)

Each of these SWZ strategies are addressed in more detail in ***Section 3***.

See Specifications ***Dev102SWZ and Dev990SWZ***, ***FDM DDC240***, and ***Developmental Standard Plans*** for additional criteria.

Since SWZ strategies augment rather than replace other work zone traffic control devices, it is important to always comply with adopted design criteria for work zones, including, but not limited to the ***Manual on Uniform Traffic Control Devices***, ***FDOT Standard Plans***, ***FDOT Design Manual (FDM)***, ***FDOT Standard Specifications for Road and Bridge Construction,*** and ***FDOT Speed Zoning for Highways, Roads, and Streets in Florida*** when selecting SWZ strategies to use on a particular project.

1.5 Smart Work Zone Operations

SWZ systems may operate in a closed environment or connect to either a cloud-based processor system or a traffic management center or both. A closed system will have preset and pre-approved algorithms for activating and updating SWZ elements such as Portable Changeable Message Sign (PCMS) or alarms. A connected system may have a combination of automatic, pre-approved elements and elements that require an engineer to provide input or approval before the system updates a SWZ PCMS or a Variable Speed Limit (VSL) sign. SWZ operations will need to be addressed in accordance with the ***FDM DDC240, Section 240.3 Transportation Operations Plan*** and ***Guidebook Sec. 4.1 - SWZ Active Management and Operations Plan. Guidebook Sec. 3*** provides operational guidance and criteria for each of the above SWZ strategies.

Chapter 2: Programming and Scoping

2.1 Work Zone Assessment for SWZ Priority

Work zones that negatively impact traffic safety and throughput are the highest priority for inclusion of SWZ strategies within the Temporary Traffic Control Plans (TTCP) (See ***FDM DDC240***). Initial screening for determining if SWZ strategies would improve traffic safety and efficiency should ideally be conducted during project scoping and development of the work programming so that costs for SWZ can be properly considered.

The requirements for including SWZ strategies and technologies on the State Highway System can be found in ***FDM DDC240***.

2.2 Design Scope of Services for SWZ Strategies

FDOT's standard design Scope of Services covers development of a TTCP for roadway projects.

- Section 4.10 Temporary Traffic Control Plan (TTCP) Analysis
- Section 4.11 Master TTCP Design Files
- Section 5 Roadway Plans
- Section 10.25 TTCP/Staged Construction Requirements
- Section 22.11 TTCP Signal (Temporary)
- Section 34.15 Temporary Traffic Control Plans

For projects including SWZ strategies and technologies, design scopes of services for design-bid-build projects and the RFP for design-build projects should address identification and design of SWZ strategies within the TTCP.

Chapter 3: Identification and Selection of SWZ Strategies

As noted in above, there are several SWZ strategies described in this SWZ Guidebook. Each strategy can address one or more specific work zone safety and traffic operations challenges.

SWZ strategies may be selected to minimize traffic and safety impacts to the roadway planned for construction. SWZ strategies may also be selected to minimize impacts to a network of roadways including the roadway under construction and roadways surrounding the work zone that may be impacted by detours or traffic diversions due to work zone congestion.

The following sections discuss each of the use case(s), concept of operations, anticipated benefits, technologies, and typical layouts for each of the five SWZ strategies listed above. Select and implement SWZ strategies on a project-by-project basis based on their potential to impact safety and mobility on the project. Similar projects with similar impacts should use the same SWZ strategies to enhance driver familiarity.

3.1 Work Zone Data Exchange (WZDx)

The Work Zone Data Exchange (WZDx) Specification enables infrastructure owners and operators to make harmonized work zone data available for third party use. The goal of the WZDx is to enhance the ability of vehicles equipped with automated driving systems (ADS) to safety and efficiently navigate through work zones.

3.1.1 WZDx Use Cases and Concept of Operations

The WZDx can be used for any project impacting roadway traffic or where workers may be present adjacent to open traffic lanes. As a minimum WZDx SWZ Location Devices are placed at the "ROAD WORK AHEAD" and the "END ROAD WORK" signs. For longer and more complex projects, SWZ Location Devices should also be considered at the following locations:

- First/last lane closure Channelization Device locations
- Flaggers using either flag paddles or flagger assistive devices
- SWZ Flashing Arrow Boards
- Vehicle mounted Flashing Arrow Boards
- Mobile work zone Shadow Vehicles and/or mobile work zone attenuator trailers
- Stop Here on Red Signs and/or on Portable Traffic Signals
- Workers in the work zone using smartphone application or wearable device

Properly placed SWZ Location Devices will allow work zone information providers to provide timely and accurate work zone information as work zone traffic control and traffic conditions changes occur (*e.g.*, speed limits, SWZ PCMS messages, lane closures).

Depending on the expected traffic volumes and length of queue, placement of SWZ Location Device should be extended upstream to ensure it is located ahead of any slowed traffic caused by the work zone.

3.1.2 WZDx Technologies

The primary roadside technology for WZDx is the SWZ Location Device, which is a global positioning system (GPS) based wireless communication device. This device sends messages to third party traveler information service providers either directly or through a SWZ Processor using WZDx specifications. The SWZ Location Device can be integrated into channelizing device, SWZ arrow boards, and SWZ PCMS.

Figure 1 is a simplified architecture of a WZDx system showing WZDx equipment, communication connectivity, and information flows between equipment.

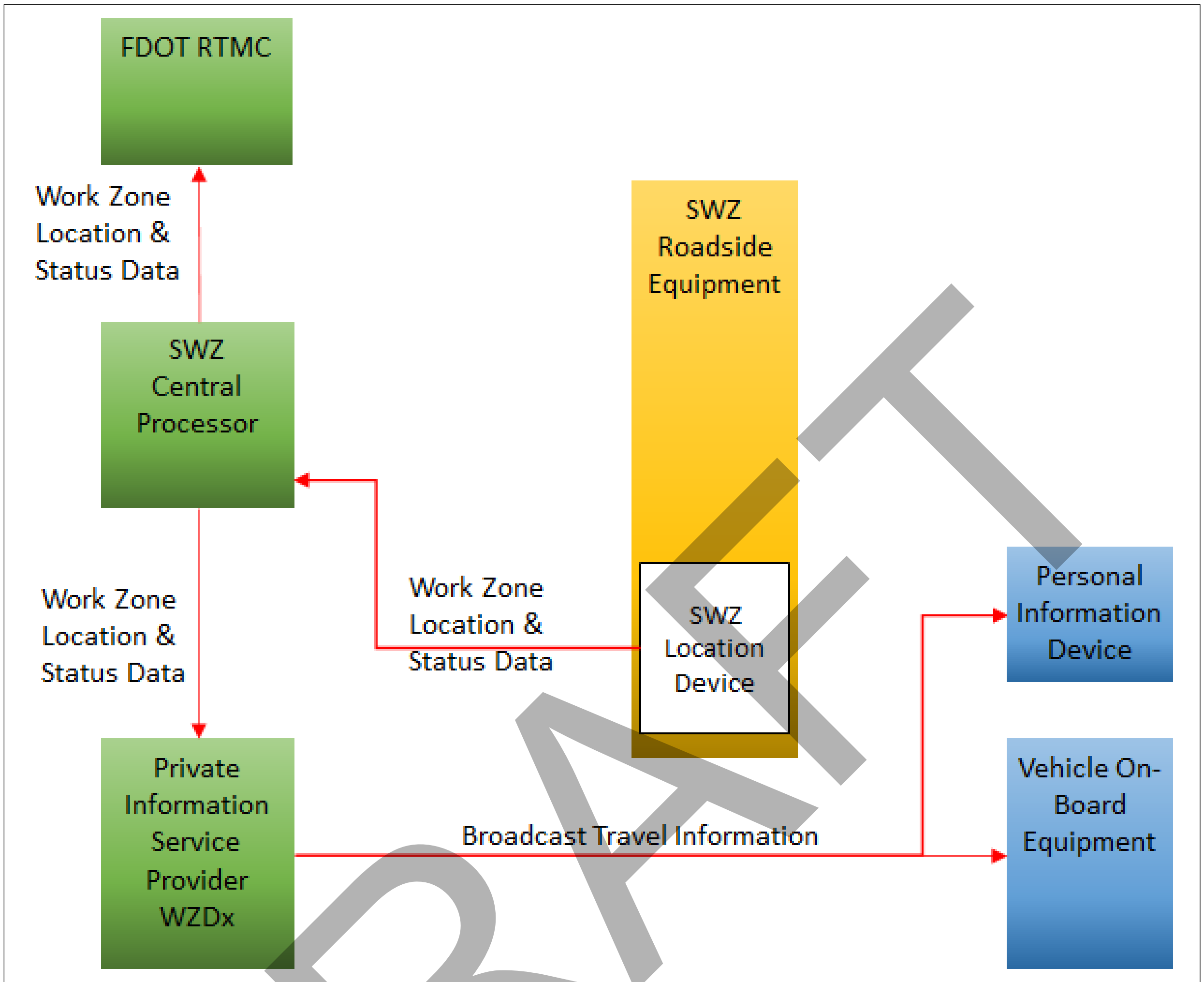


Figure 1: WZDx Basic Architecture

3.1.3 WZDx Basic Layout

The basic layout for the WZDx is to provide SWZ Location Devices adjacent to the "ROAD WORK AHEAD" and "END ROAD WORK" signs in all TTCP.

3.2 Dynamic Lane Merge (DLM)

The National Work Zone Safety Information Clearinghouse *Guidance for the Use of Dynamic Lane Merging Strategies* (November 2012) describes how dynamic early merging and dynamic late merging can be used either individually or cooperatively to reduce delay and increase safety at highway lane closures.

3.2.1 DLM Use Case

Use DLM when traffic speeds and volumes typically and predictably change throughout the duration of the lane closure. When a lane closure is present, some drivers tend to move over immediately while others wait until the last possible moment to merge. This driver behavior causes speed differentials, hard braking, road rage, crashes, endangers workers, and reduces throughput in the lanes approaching the lane closure and in the open lanes past the closure.

3.2.2 DLM Concept of Operations

DLM has two modes of operations: DLM-Late Merge and DLM-Early Merge.

- DLM-Late Merge works best when approaching traffic volumes are nearing or exceed the capacity (1,500 vehicle/lane/hour) of the remaining open lanes.
- DLM-Early Merge works best for low traffic volumes to get all traffic into the open lanes early so that they are traveling at uniform speeds when they approach the closure.

For work zones with geometric restrictions, closed or narrow shoulders, and/or lane closures, speed reductions, sudden speed changes, queues, and delays are predictable when approaching traffic volumes near the capacity of the restricted roadway. Capacity analysis plus operational experience are used to anticipate conditions for use of DLM and to implement changes between DLM-Late Merge and DLM-Early Merge to reduce queue lengths and delay.

Use of DLM allows the maintenance of traffic manager to dynamically or manually switch between early and late merge as traffic conditions change through the duration of the lane closure. DLM can use a SWZ Central Processor using pre-approved algorithms to switch between DLM modes. Planning for use of both Early and Late merge modes should be based on historical traffic volumes. Timing of switch between modes should be based on real-time traffic conditions, however, quickly switching back and forth between modes is not recommended.

DLM can create more orderly merging conditions at lane closures by communicating to drivers through SWZ PCMS or through vehicle on-board units (e.g., OBUs). The messages displayed direct drivers to merge early when traffic conditions are light and merge late when traffic conditions are heavy. When high traffic speeds are detected with low traffic volumes, DLM activate SWZ PCMS messages for the early merge mode. When low traffic speeds are detected and traffic volumes are high, DLM activates SWZ PCMS messages for the late merge mode. Timing of switching between modes will depend on traffic speed and volume trends.

Depending on the expected traffic volumes and length of queue, extend coverage of SWZ PCMS upstream to ensure the first SWZ PCMS is ahead of any slowed traffic caused by the work zone especially when traffic volumes and speeds suggest DLM Late Merge option is needed.

Benefits anticipated with DLM – Late Merge include:

- Reduced stop and go flow
- Increased throughput through the work zone
- Fewer crashes
- Increased queue storage, reducing potential for backups into upstream ramps and intersections
- Fewer work zone intrusions

Benefits experienced with DLM – Early Merge include:

- Fewer last moment “cut-ins”
- Increased throughput through the work zone
- Fewer crashes
- Fewer work zone intrusions

3.2.3 DLM Technologies

To manage traffic through temporary lane closures, Dynamic Lane Merge uses the following SWZ devices and systems:

- SWZ Location Devices
- SWZ Arrow Boards
- SWZ Vehicle Detectors
- SWZ PCMS
- SWZ Central Processor

SWZ Vehicle Detectors collect traffic speed and volume data and transmit the data to the SWZ Central Processor. The SWZ Central Processor determines the optimal DLM Mode of Operations and transmits messages to post on the SWZ PCMS.

SWZ PCMS messages vary depending on mode of operation. SWZ PCMS messages for DLM stored in the SWZ Central Processor must be approved by FDOT for use with DLM operational scenarios. Once the PCMS message library in the SWZ Central Processor is approved along with the usage algorithms for each message, no further FDOT approvals are needed unless a message or usage algorithm is changed. ***Tables 2 & 3*** lists PCMS messages that may be used for early and late operational modes.

Table 2: DLM - Early Merge PCMS Messages

DLM – Early Merge PCMS Messages			
PCMS Position	**PCMS Line #**	**PCMS Page 1**	**PCMS Page 2**
First PCMS seen by traffic (Use additional PCMS with applicable distances depending on length of traffic backup)	1	RT LANE	MERGE
	2	CLOSED	LEFT
	3	1 MILE	
Second PCMS seen by traffic	1	RT LANE	MERGE
	2	CLOSED	LEFT
	3	1/2 MILE	
Third PCMS seen by traffic	1	RT LANE	MERGE
	2	CLOSED	LEFT
	3	1/4 MILE	

Table 3: DLM - Late Merge PCMS Messages

DLM – Late Merge PCMS Messages			
PCMS Position	**PCMS Line #**	**PCMS Page 1**	**PCMS Page 2**
First PCMS seen by traffic (Use additional PCMS with applicable distances depending on length of traffic backup)	1	RT LANE	STAY
	2	CLOSED	IN
	3	1 MILE	LANE
Second PCMS seen by traffic	1	RT LANE	STAY
	2	CLOSED	IN
	3	1/2 MILE	LANE
Third PCMS seen by traffic (Last PCMS before the merge point)	1	MERGE	TAKE
	2	LEFT	TURNS
	3	HERE	

Figure 2 provides a simplified architecture of a DLM system showing DLM equipment, communication connectivity, and information flows between equipment. This architecture is identical for DQW.

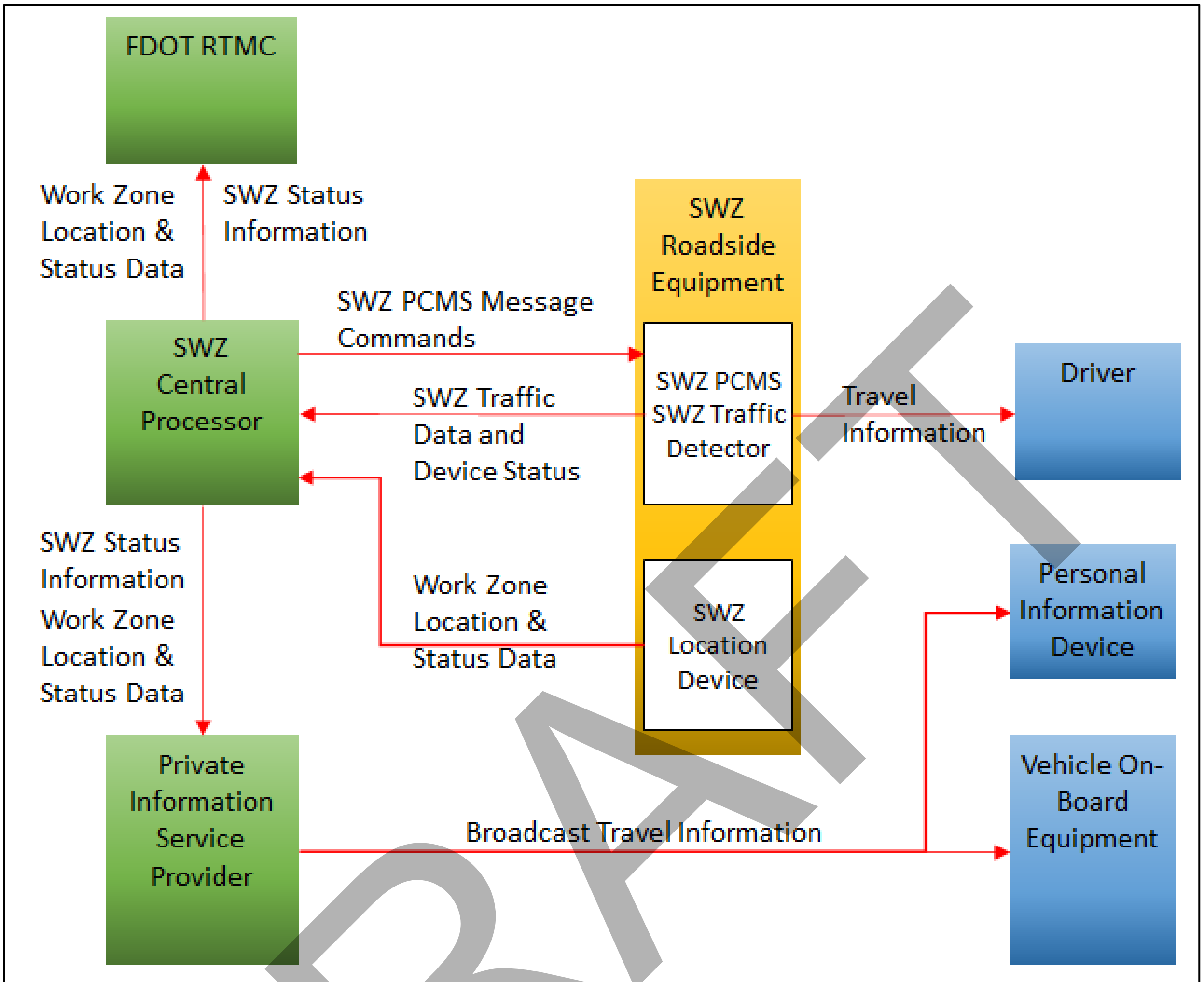


Figure 2: DLM Basic Architecture

3.2.4 DLM Conceptual Layout

DLM use to operational concepts: Early Merge and Late Merge. ***Figure 3*** is conceptual layout of early merge while ***Figure 4*** is a conceptual layout of late merge.

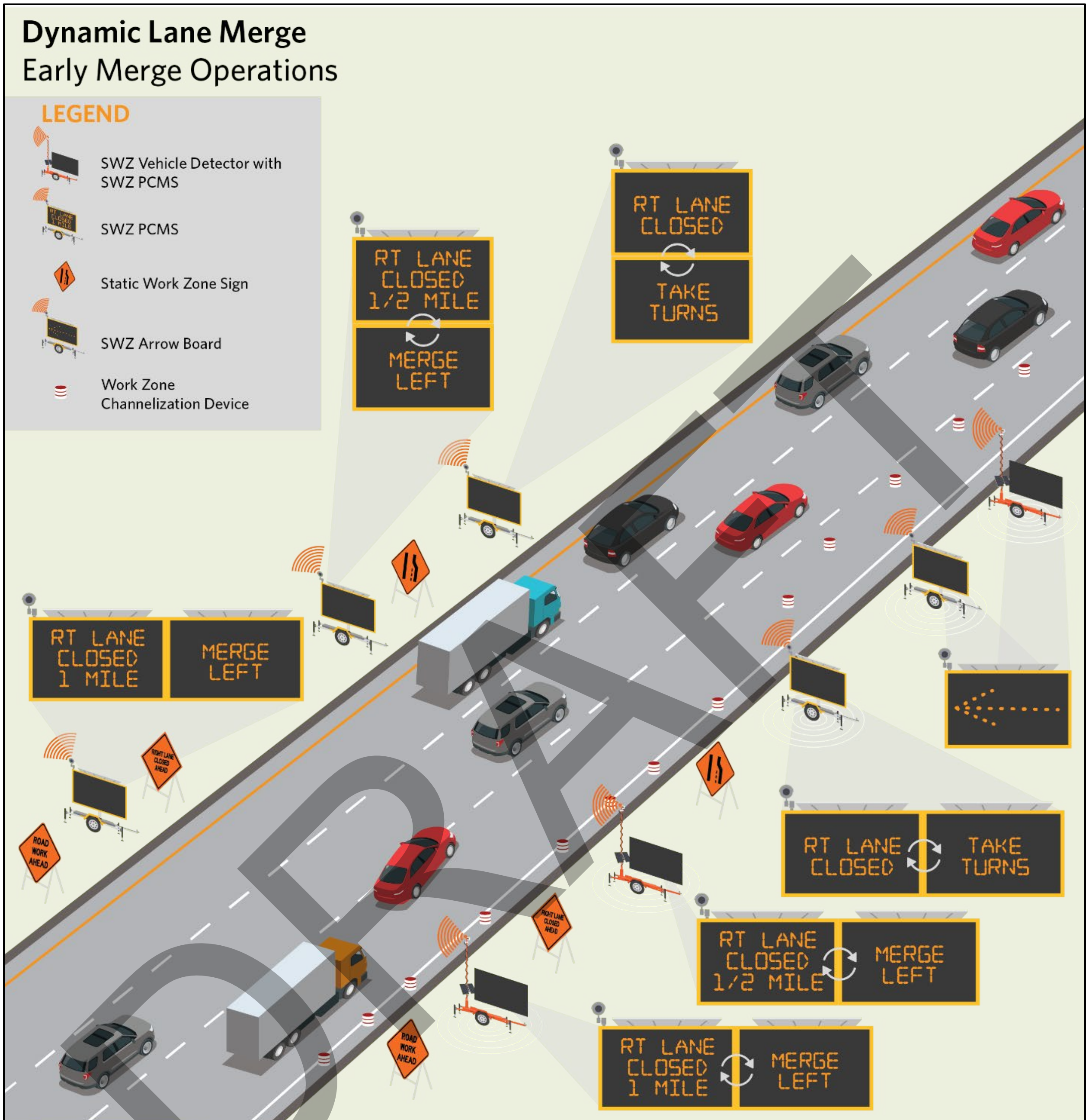


Figure 3: Dynamic Lane Merge - Early Merge Operations

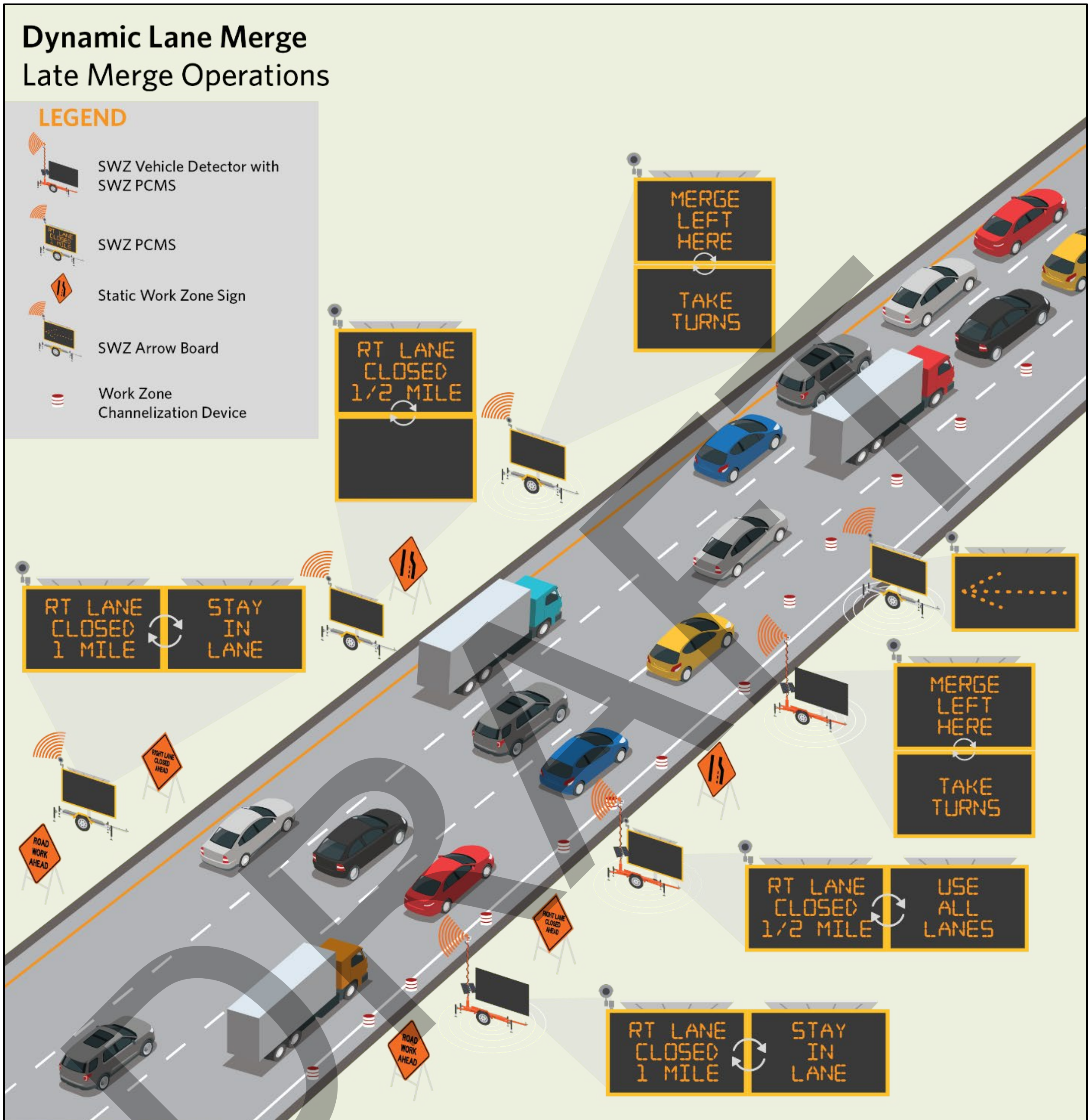


Figure 4: Dynamic Lane Merge - Late Merge Operations

More DLM layout details are depicted in **Developmental Standard Plans** for **Indices 102-613 and 102-620.**

3.3 Dynamic Speed Harmonization (DSH)

Per Architecture Reference for Connected and Intelligent Transportation (***ARC-IT) Version 9.0, [Service Package TM21](): Speed Harmonization***, the purpose of speed harmonization is to change traffic speed on links that approach areas of traffic congestion, bottlenecks, incidents, special events, and other conditions that affect flow. Speed harmonization assists in maintaining flow, reducing unnecessary stops and starts, and maintaining consistent speeds. The speed limits generated by the speed harmonization strategy can be provided to in-vehicle on-board equipment or through VSL signs as shown in **Figure 5**.

3.3.1 DSH Use Cases

There are two basic reasons to use DSH in work zones.

1. Use Dynamic Speed Harmonization (DSH) when traffic speeds vary through the work zone and/or where traffic speed approaching the work zone is considerably higher than speed through the work zone.
2. Use DSH when different speed limits are needed when workers are present, for example, compared to when workers are not present.

3.3.2 DSH Concept of Operations

This strategy requires active management of work zone regulatory speed limits based on approaching traffic speeds and 85th percentile slowest speeds through the work zone. Speed Harmonization has been used to gradually slow or smooth traffic approaching the speed constriction based on real-time conditions rather than at one VSL sign in advance of the work zone. VSL speed limit messages always presented in whole 5 miles per hour (MPH) increments. The SWZ Central Processor will generate speed limit messages based on VSL sign locations and traffic speeds. The SWZ Central Processor speed limit generation algorithms and tables must be approved in advance by the District Traffic Operations Engineer, or delegate, responsible for setting speed limits. See Table 4 for an example of speed limit generation table based on speeds of approaching traffic and speeds in the downstream bottleneck. In accordance with the FDOT Speed Zoning Manual Section 10.1(c), a human operator approved by the Department must review and accept the SWZ Central Processor generated speed limits prior to posting them on the VSL signs.

Electronic speed feedback signs (ESFS) and presence of a law enforcement officers have been shown to increase speed limit compliance. For DSH, ESFS are located with each VSL sign and integrated with the VSL sign either at the roadside or in the SWZ Central Processor so that any alerts the ESFS provides when a speeding vehicle is detected are based on the current speed limit posted on the VSL sign.

Depending on the expected traffic volumes and length of queue, extend coverage of SWZ PCMS upstream to ensure the first SWZ PCMS is ahead of any slowed traffic caused by the work zone.

Types of benefits anticipated with DSH include:

- Reduced stop and go flow
- Reduced speed variation
- Increased throughput through the work zone
- Fewer crashes
- Possibility for longer construction hours

Table 4: VSL Messages Based on Speed and Bottleneck Speed

Variable Speed Limits Based on Measured Traffic Speeds						
85th Percentile Measured Speed within the Work Zone	VSL #1	VSL #2	VSL #3	VSL #4	VSL #5	Additional VSL Sign(s) Preceding and through WZ Lane Restriction
	Posted Variable Speed Limit (VSL)					
> 65 MPH	65 MPH	65 MPH	65 MPH	65 MPH	65 MPH	65 MPH
60 – 64 MPH	65 MPH	65 MPH	65 MPH	65 MPH	65 MPH	65 MPH
55 – 59 MPH	65 MPH	65 MPH	60 MPH	60 MPH	60 MPH	60 MPH
50 – 54 MPH	65 MPH	65 MPH	60 MPH	55 MPH	55 MPH	55 MPH
45 – 49 MPH	65 MPH	65 MPH	60 MPH	55 MPH	50 MPH	50 MPH
40 – 44 MPH	65 MPH	60 MPH	55 MPH	50 MPH	45 MPH	45 MPH
< 40 MPH	60 MPH	55 MPH	50 MPH	45 MPH	40 MPH	40 MPH

PCMS are used to warn drivers when speeds are reduced. Typically, PCMS are placed half-way between VSL signs, as follows:

- PCMS → VSL → PCMS → VSL, etc., as needed.

Table 5: DSH PCMS Messages

PCMS Position	PCMS Line #	PCMS Page 1
First PCMS seen by traffic (Use additional PCMS with applicable distances depending on distance to traffic bottleneck)	1	REDUCE
	2	SPEED
	3	1 MILE
Second PCMS seen by traffic	1	REDUCE
	2	SPEED
	3	1/2 MILE
Third PCMS seen by traffic	1	REDUCE

PCMS Position	PCMS Line #	PCMS Page 1
(Last PCMS before the speed bottleneck)	2	SPEED
	3	1/4 MILE

3.3.3 DSH Technologies

To manage traffic through temporary lane closures and through lane shifts and traffic “cross-overs”, Speed Harmonization uses the following SWZ technologies:

- SWZ Location Devices
- SWZ Arrow Board (at lane closure points)
- SWZ Vehicle Detectors
- SWZ PCMS
- VSL Signs with ESFS

For DSH, driver compliance with SWZ VSL speed limits increase when ESFS are provided as well. Since SWZ VSL posted speed limits may change from time to time, it is essential the VSL signs and ESFS function in an integrated manner in DSH. The ESFS speeding alerts are tied to the actual speed limit posted in the VSL sign so that the alerts become active when an approaching vehicle is detected traveling at one (1) MPH over the speed limited posted in the VSL sign. As the VSL sign message changes, the ESFS alarm adjusts at the same time.

Figure 5 provides a basic architecture for DSH.

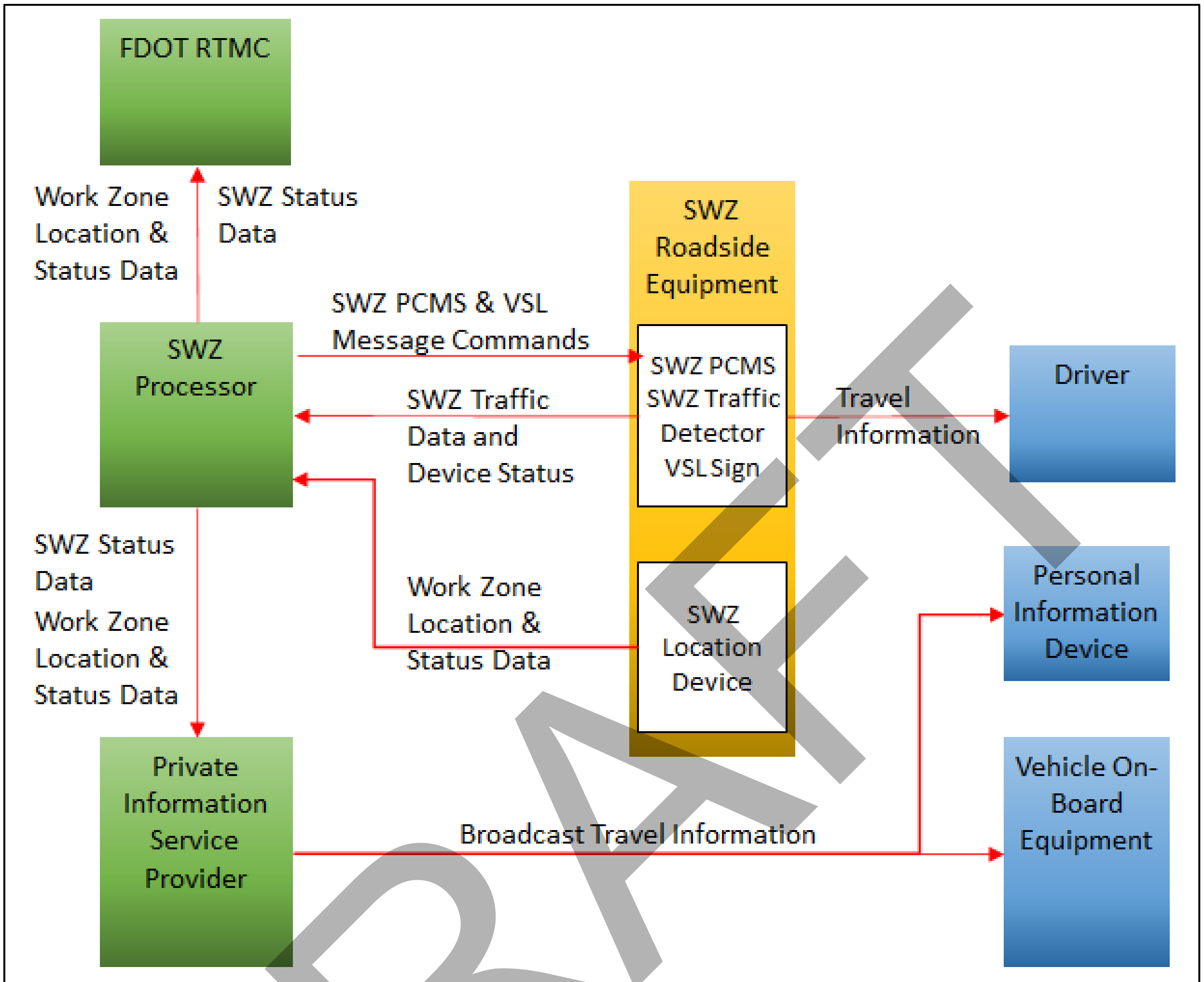


Figure 5: DSH Basic Architecture

3.3.4 DSH Layouts

Figure 6 provides a conceptual layout for DSH. Detailed layouts are provided in ***Development Standard Plans***, ***Indexes D102-613 and 102-620***.

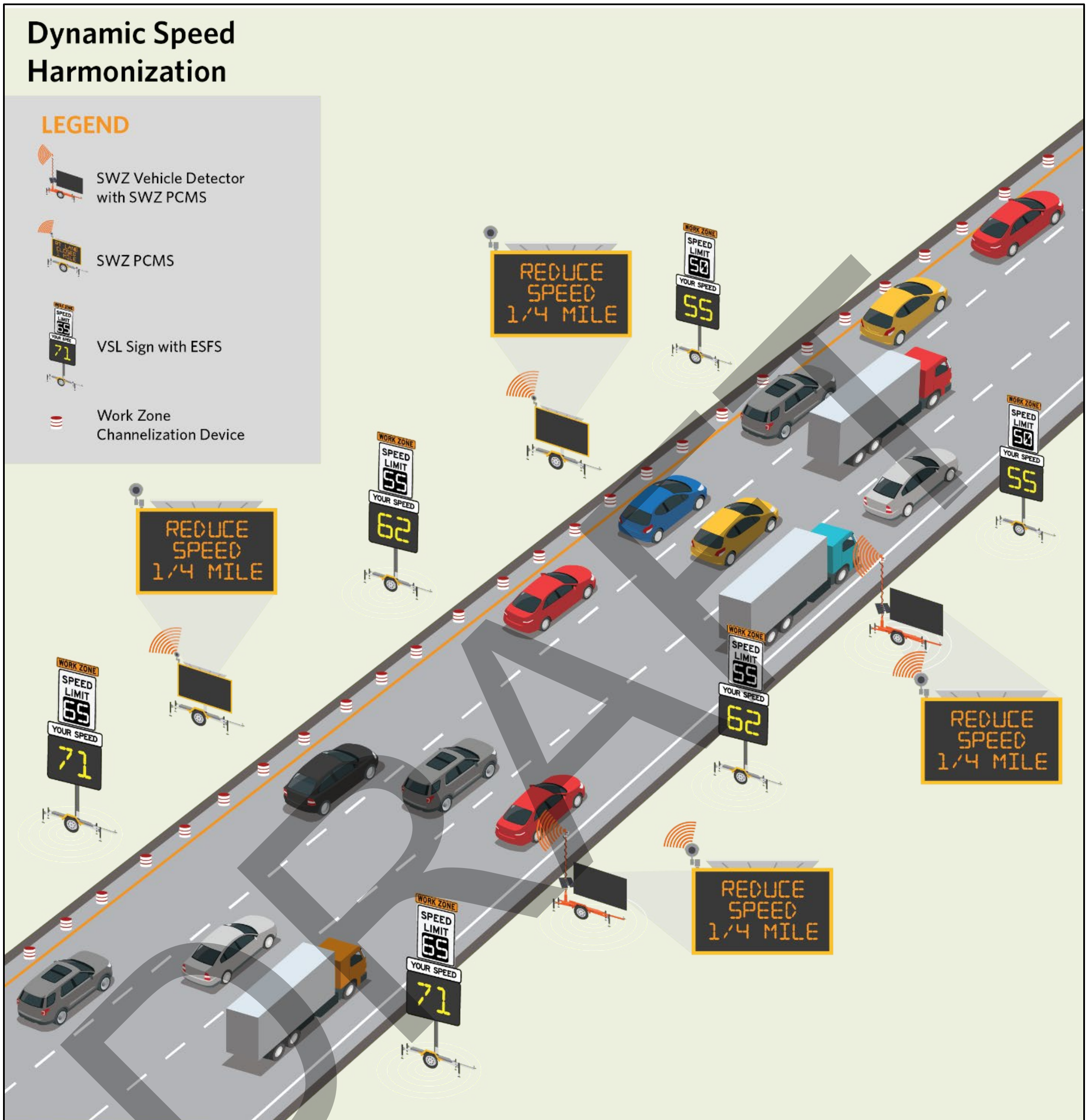


Figure 6: Dynamic Speed Harmonization

3.4 Dynamic End of Queue / Slow Speed Warning

Dynamic End of Queue/Slow Speed Warning (DQW) systems follow the general layout of ***Standard Plans Index 102-613*** except that SWZ traffic detectors and SWZ PCMS are added as indicated in ***Developmental Standard Plans, Indexes D102-613*** and ***D102-620***. The SWZ Traffic Detectors and SWZ PCMS communicate with the SWZ Central Processor. The SWZ Central Processor selects and posts SWZ PCMS messages from an FDOT approved PCMS message library based on real-time traffic conditions, speeds, and end of queue location when slow speeds or stopped traffic are detected downstream from each PCMS.

3.4.1 DQW Use Cases

Use DQW system to detect slow speed approaching and through the work zone. The slow speed could be caused by either the work zone traffic control or a traffic incident. Goal is to encourage traffic to gradually slow as it approaches a bottleneck impacting traffic speeds.

3.4.2 DQW Concept of Operations

Use SWZ Traffic Detectors to measure speeds and volumes of traffic approaching and through the work zone lane closure(s) and traffic constrictions. When speeds in the work zone are between 50% and 85% of approaching speeds, use SWZ PCMS to warn traffic of slow traffic and distance ahead to the back of the slow speed queue. When work zone speed is less than 50% of approaching traffic speeds, use SWZ PCMS to for “stopped traffic ahead”, “stopped traffic xx miles”. Manage DQW with the SWZ Central Processor, or the traffic management center.

SWZ PCMS messages stored in the SWZ Central Processor must be approved by FDOT for use with DQW operational scenarios. Once the PCMS message library in the SWZ Central Processor is approved along with the usage algorithms for each message, no further FDOT approvals are needed unless a message or usage algorithm is changed. See ***Table 6*** for a set of PCMS messages for specific algorithms.

Depending on the expected traffic volumes and length of queue, extend coverage of PCMS upstream to ensure the first SWZ PCMS is ahead of any congestion or queue caused by the work zone.

Benefits experienced with DQW include:

- Fewer work zone crashes
- Increased throughput through the work zone

Table 6: DQW PCMS Messages - Slow Traffic Ahead

DQW PCMS Messages – Slow Traffic Ahead			
PCMS Position	**PCMS Line #**	**PCMS Page 1**	**PCMS Page 2**
First PCMS seen by traffic (Use additional PCMS with applicable distances depending on length of traffic backup)	1	SLOW	SLOW
	2	TRAFFIC	TRAFFIC
	3	1 MILE	AHEAD
Second PCMS seen by traffic	1	SLOW	SLOW
	2	TRAFFIC	TRAFFIC

DQW PCMS Messages – Slow Traffic Ahead			
PCMS Position	**PCMS Line #**	**PCMS Page 1**	**PCMS Page 2**
	3	1/2 MILE	AHEAD
Third PCMS seen by traffic (Last PCMS before the merge point)	1	SLOW	SLOW
	2	TRAFFIC	TRAFFIC
	3	1/4 MILE	AHEAD

Table 7: DQW PCMS Messages - Stopped Traffic Ahead

DQW PCMS Messages – Stopped Traffic Ahead			
PCMS Position	**PCMS Line #**	**PCMS Page 1**	**PCMS Page 2**
First PCMS seen by traffic (Use additional PCMS with applicable distances depending on length of traffic backup)	1	STOPPED	PREPARE
	2	TRAFFIC	TO
	3	1 MILE	STOP
Second PCMS seen by traffic	1	STOPPED	PREPARE
	2	TRAFFIC	TO
	3	1/2 MILE	STOP
Third PCMS seen by traffic (Last PCMS before the merge point)	1	STOPPED	PREPARE
	2	TRAFFIC	TO
	3	1/4 MILE	STOP

DQW and DLM or DSH may be used in combination.

3.4.3 DQW Technologies

To manage traffic through temporary lane closures, DQW uses the following SWZ devices and systems:

- SWZ Location Devices
- SWZ Arrow Boards at lane closures
- SWZ Vehicle Detectors
- SWZ PCMS
- SWZ Central Processor

SWZ Vehicle Detectors collect traffic speed and volume data and transmit the data to the SWZ Central Processor. The SWZ Central Processor determines the distance from each SWZ PCMS to the end of the queued traffic ahead. The Processor also determines if the traffic is “stopped” or “slow” and transmits appropriate messages to post on the SWZ PCMS.

Figure 7 provides a basic architecture for DQW. The physical architecture is identical to DLM. The primary difference is that the SWZ Central Processor is determining SWZ PCMS messages based on the DQW operational concept.

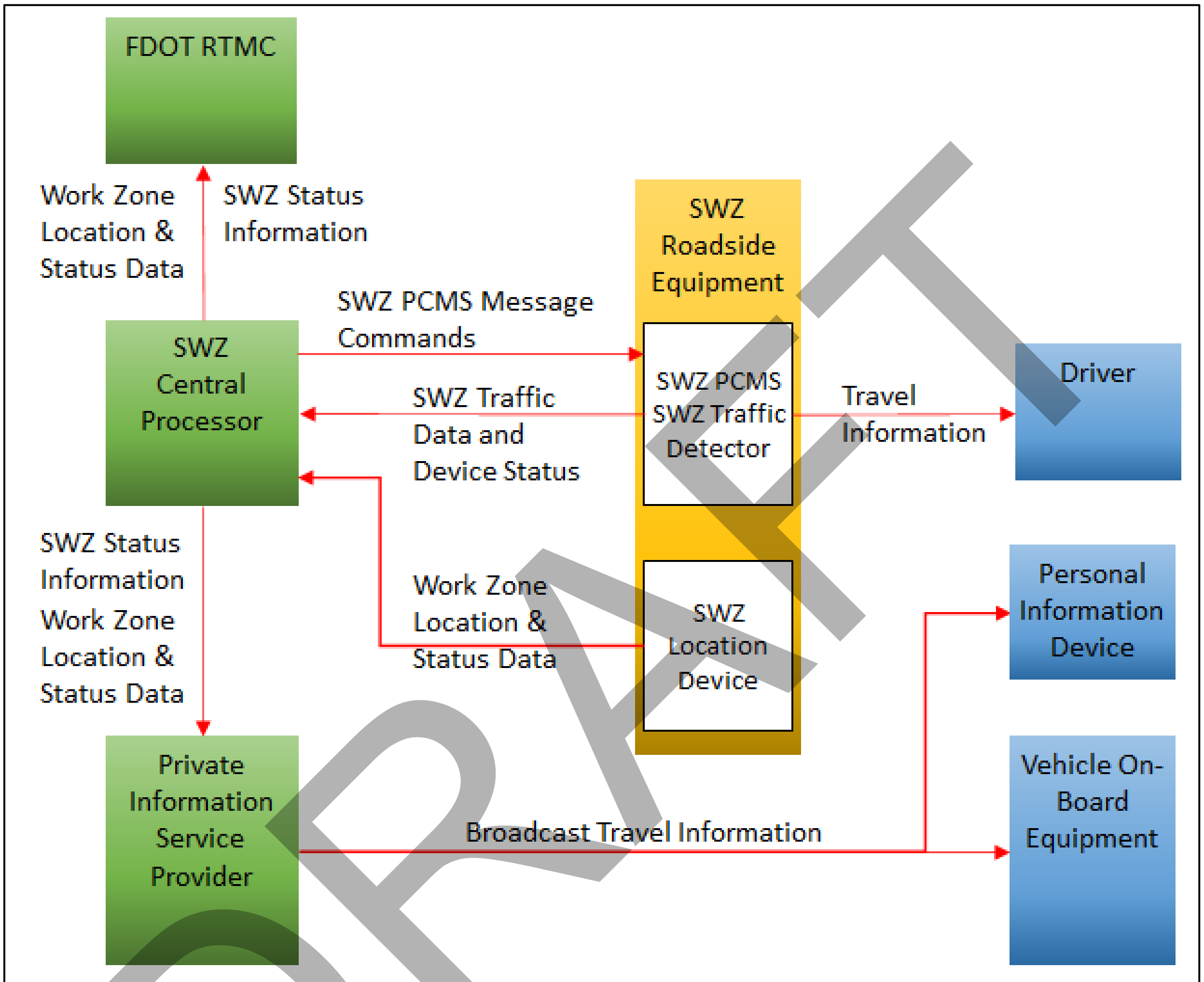


Figure 7: DQW Basic Architecture

3.4.4 DQW Layouts

Figure 8 provides a conceptual layout for DQW. Additional DQW design details are provided in ***Developmental Standard Plans***, ***Indexes D102-613*** and ***D102-620***.

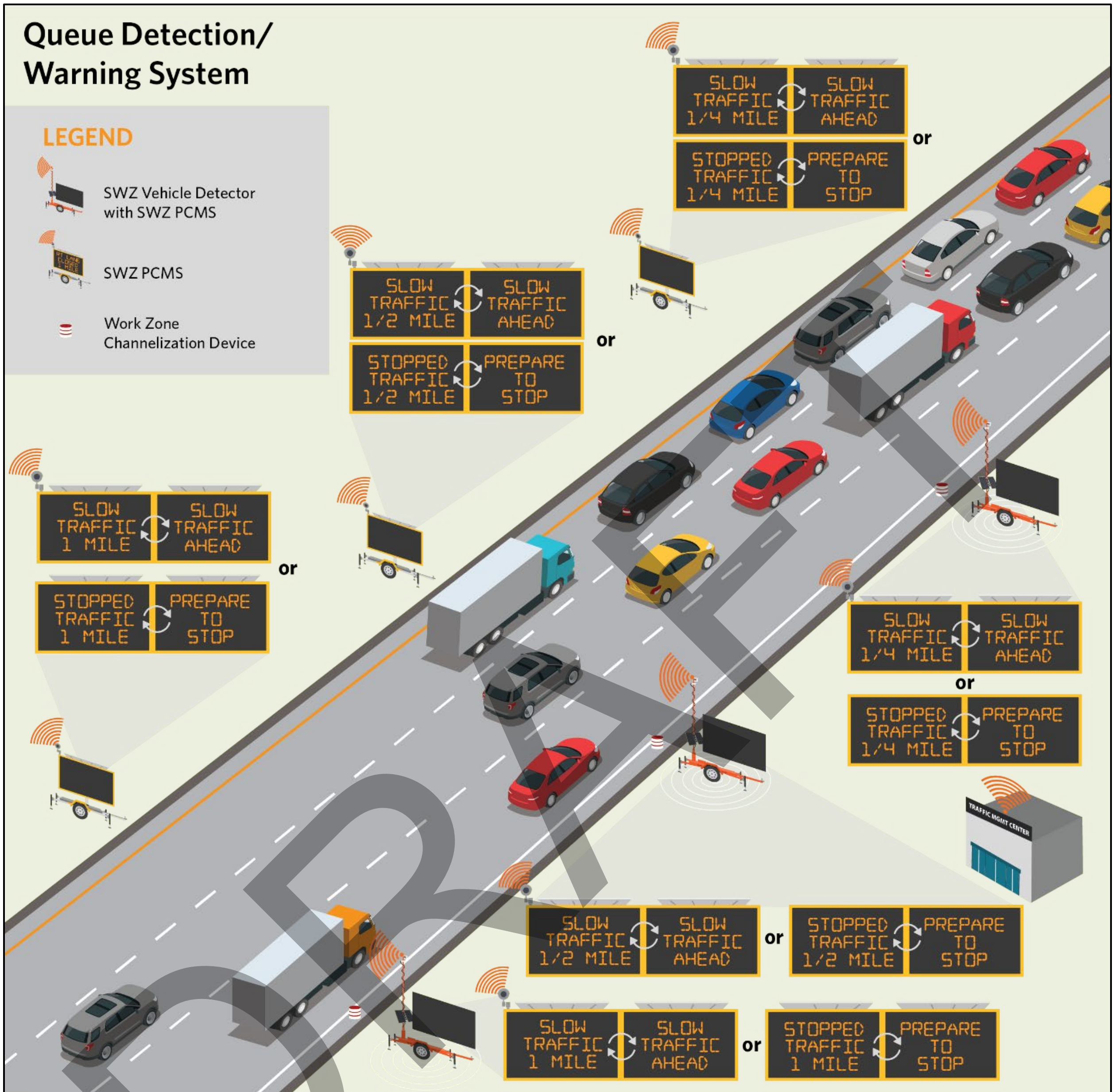


Figure 8: Dynamic Queue Detection and Warning

3.5 Dynamic Intrusion Detection and Warning (DIW)

Per ***ARC-IT*** ***Service Package MC:07*** ***Work Zone Safety Monitoring***, work zone protection and warning strategies provide warnings to construction and maintenance personnel within a work zone about potential hazards within the work zone. It enables vehicles or the infrastructure to provide warnings to workers in a work zone when a vehicle is moving in a manner that appears to create an unsafe condition, e.g., entering the work zone. **Figure 8 Work Zone Intrusion Warning Basic Architecture** depicts both broadcast and personnel intrusion safety warning devices and messages.

Intrusion detection technology layouts must locate the detection devices so that the entire area of the work zone approaching locations where workers are present is circumscribed by the detectors' detection zone. The layout should also include a buffer between the intrusion area and workers so that workers have time to take evasive action and vehicles have time to stop. Placement of intrusion alarms should avoid locations where the alarm visual alarm might be occluded by construction vehicles and the audible alarm might be obscured by equipment noise.

Visual and/or audible alarms must be placed where they are within visual line-of-sight and hearing distance of workers. For audible alarms, the minimum volume should be 10 decibels (dB) higher than the surrounding ambient noise level or 85 dB, whichever is higher. Use a factor of 6 dB reduction in volume for every doubling of distance from the audible alarm, for example: 125 dB at 10 feet is 109 dB at 20 feet, 103 dB at 40 feet, 98 dB at 80 feet, 92 dB at 160 feet, etc. If workers are wearing noise protection equipment as required by OSHA for work areas exceeding 85 dB, minimum volume at the worker location should be 95 dB to ensure workers can hear the siren. Elongated work areas may require multiple Intrusion detection and warning systems to meet ensure full protection of the work area.

3.5.1 DIW Use Cases

Use DIW when workers are in the work area and separated from traffic by only barrels or cones. The closer the workers are in proximity to traffic, the higher the potential for a vehicle entering the work zone to impact a worker.

DIW utilize alarms activated by the detection system via wireless communication. Alarms may be signs with beacons, signs with rapid flashing light-emitting diode (LED) lights, and/or audible alarms. The alarms are located far enough ahead to provide warning to workers or motorists in time to take evasive action. If workers are stationary, fixed locations of alarms are practical. If workers are mobile, then use of wearable audible and haptic alarms should be considered. Most DIW vendors provide a portable warning device that can be worn or held by the worker.

3.5.2 DIW Concept of Operations and Technologies

To manage and mitigate the impacts of private vehicles mistakenly entering work areas or work vehicles entering, exiting, or crossing work areas, DIW strategies utilize the following technologies and devices:

1. SWZ Intrusion Detector: Portable traffic intrusion (presence) detectors to detect a vehicle crossing from the open lanes into the work area
2. Alarms: Use visible and audible alarms when a vehicle intrusion is detected

3. Personal Alarms: Use personal audible/haptic alarm devices worn by or near workers which are also activated when intrusion is detected, especially if the worker located far from the stationary alarm or in a high-noise environment.
4. Consider use of vehicle-mounted or trailer-mounted attenuators to protect the work zone.
5. If the work zone is mobile, consider autonomous truck mounted attenuator behind the work area to protect workers and construction vehicles.

Other recommendations for wearable alarms for DIW include:

- Locating the worker using a GPS location device
- Using cellular communication to send the worker's location data to the WZDx to share worker presence data with the WZDx and with CAV roadside unit
- Receiving intrusion or other alerts from work zone intrusion and other devices
- Generating audible, tactile, and/or visible alarms for the worker when alerts are received

Benefits experienced with DIW include reduced crashes with workers.

Figure 9 provides a basic architecture showing DIW device connectivity and data communication paths.

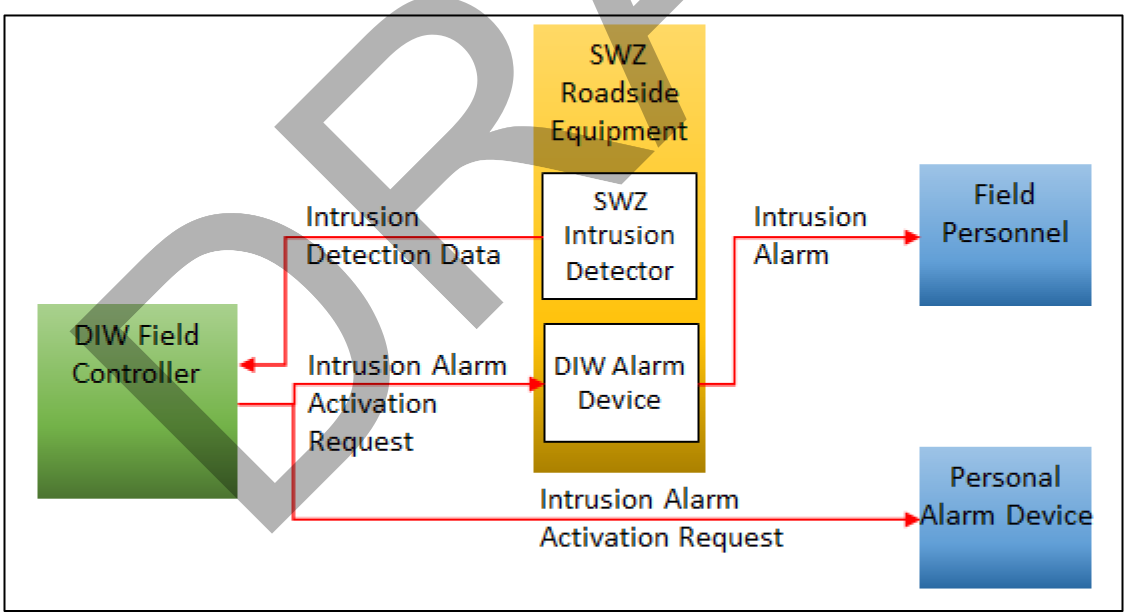


Figure 9: DIW Basic Architecture

3.5.3 DIW Layouts

Figure 10 provides a conceptual layout for DIW. Actual layouts will depend on the technologies available from manufacturers and vendors of DIW systems.

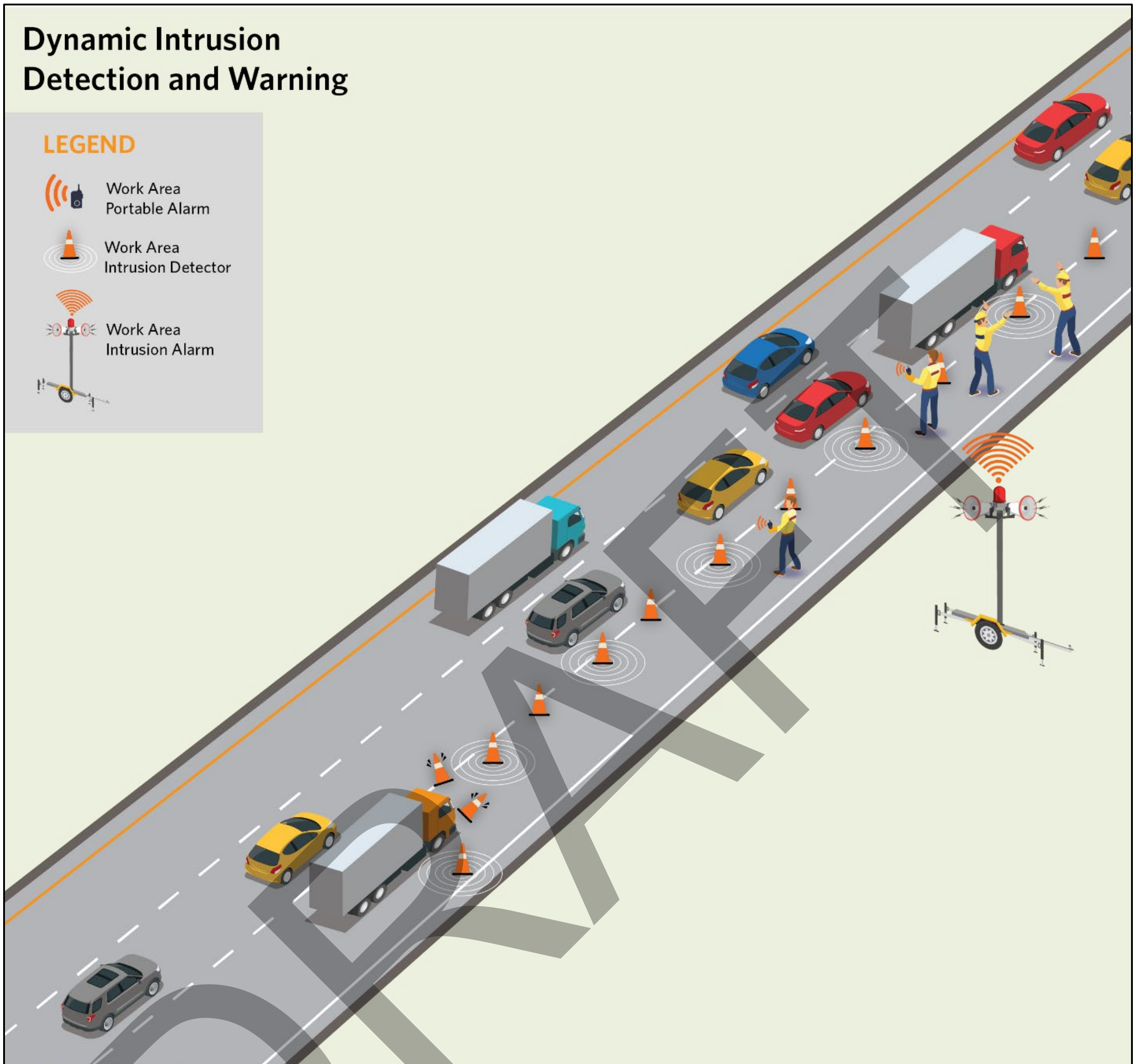


Figure 10: Dynamic Intrusion Detection and Warning (DIW) Layout

Chapter 4: SWZ Systems Engineering Analysis

Either as a part of the overall project development or separately, develop the SWZ systems engineering analysis including, as a minimum, a concept of operations (ConOps), a system verification plan, a system validation plan, and a project system engineering management plan (PSEMP) as required by the FDOT Systems Engineering and Intelligent Transportation Systems (ITS) Architecture Procedure (*Procedure # 750-040-003*). The level of detail in the systems engineering analysis must be commensurate with the risk and magnitude of the SWZ elements planned for the project.

4.1 SWZ Active Management and Operations Plan

When using SWZ, development of the ***FDM Sec. 240.3 Transportation Operations Plan*** is mandatory. The SWZ Operations Plan identifies roles and responsibilities, user interfaces, software, and data storage to manage roadside data and manage SWZ roadside devices and cellular communications.

A Management and Operations Plan is required for projects using Dynamic Lane Merge, Speed Harmonization, and Dynamic Queue Detection and Warning, and other SWZ strategies where a SWZ Central Processor is used for SWZ Traffic Detector data collection, central data processing, real-time data sharing, and real-time management of SWZ-PCMS messages, VSL Sign speed limits, and alerts are part of the implemented SWZ plans.

The Management and Operations Plan will include the following at a minimum:

- Identification of SWZ technologies and strategies.
- Identification of safety and traffic operations goals for each SWZ strategy.
- Identification of all stakeholders with a role in design, procurement, set-up, management, operations, and adjusting of SWZ technologies and strategies.
- Identification of roles and responsibilities of each SWZ stakeholder.
- Identification of specific roles retained to FDOT for each SWZ strategy, if any.
- Formal or informal agreements, as needed, ensuring each stakeholder will meet their roles and/or responsibilities.
- Other operations and maintenance topics identified in the project ConOps.

The SWZ Management and Operation Plan should be approved by FDOT prior to finalization of SWZ strategy selection and final design plans for design-bid-build projects and before the request for proposals for design-build projects.

4.1.1 SWZ Roles and Responsibilities

As a minimum, the SWZ Management and Operations Plan must address roles and responsibilities of the Contractor (both traditional TTC staff and SWZ staff), the Construction Engineering and Inspection (CEI) inspectors, the FDOT Regional Transportation Management Center (RTMC), and appropriate law enforcement agencies such as the Florida Highway Patrol (FHP), local agency police department, county sheriff's office. If the SWZ strategies impact traffic on roadways managed by local agencies, roles and responsibilities should be defined for the local agency or agencies as well. See **Table 7** for example of SWZ roles and responsibilities. Not all Stakeholders in **Table 8** will be involved with SWZ Management and Operations. The project's ConOps (See **FDOT Procedure 750-040-003**) will contain a complete list of Project Stakeholders and Roles.

Table 8: Example SWZ Management and Operations Roles

Stakeholder	Project Role
Roadway and Temporary Traffic Control (TTC) Design Engineers	Select appropriate SWZ strategies based on specific project needs. Develop TTCP with SWZ technology elements to support TTC for the roadway construction projects. Develop SWZ Management and Operations Plan.
Roadway Contractors, Traffic Control Subcontractors	Provide, implement, integrate, manage, and maintain SWZ deployments along with overall project traffic control.
SWZ Equipment Manufacturers and Vendors	Provide SWZ equipment that meet FDOT Standard Specifications for Road and Bridge Construction. Provide SWZ cloud-based processing, management, and real-time information dissemination system. Provide necessary user training and technical support to RTMC managers and operators.
Construction Inspection Engineers and Inspectors	Ensure SWZ technologies are implemented and functioning as intended.
RTMC Managers and Operators	Monitor and interact with SWZ applications to manage and approve specific outputs from the cloud-based processing and management system.
Traffic Operations Engineer	Review and approve/deny suggested variable speed limit changes based on established algorithmic calculations. Designate representative in their absence.
Evaluators and Researchers	Download and SWZ Central Processor data and other traffic and safety data to conduct impact assessments per evaluation plans.
Law Enforcement Officers (LEO)	Park to be visible to traffic in the work zone and enforce the speed limits as need arises.
Third-Party Travel Information Providers	Disseminate SWZ info to motorists, bicyclists, and pedestrians.
Motorists, Bicyclists, and Pedestrians	Obtain SWZ information and respond accordingly.
Planners and Policymakers	Analyze SWZ Data to monitor deployment plans and policies and adjust as needed in the future.
Construction Workers/Traffic Control Field Staff	Use wearable devices and/or smartphone applications for vehicle intrusion alarms

It is important that each stakeholder with an active role is aware of their role(s) and has agreed to perform those roles and has adequate resources to do so. If necessary, a formal agreement should be executed documenting roles and responsibilities.

4.1.2 SWZ Central Processor, User Interface, Servers, and Data Storage

The SWZ Management and Operation Plan must provide requirements for the SWZ Central Processor processing software, user or operator interface with the processing software, server requirements, and data storage requirements. The SWZ Central Processor must have the following minimum capabilities plus any additional capabilities identified through Stakeholder coordination:

- Two-way communication with roadside equipment including detectors, PCMS, VSL signs, and CAV Roadside Units (RSUs).
- Server-based or located in a secure "cloud" environment
- Recommending and posting real-time VSL information based on traffic conditions and pre-approved criteria
- Generating PCMS messages using pre-approved messaging criteria based on a pre-approved message library
- Ability to provide opportunity for FDOT assigned person to review processor-generate VSL information and PCMS messages before posting them to the roadside devices
- Ability for speed limit and PCMS message generation criteria to be updated and approved by FDOT
- Ability for PCMS message library to be updated and approved by FDOT
- A user interface that is:
    - Secure
    - Internet-accessible
    - Accessible by multiple FDOT-approved users
    - Intuitive to users
- Ability to store data and provide access to data for FDOT and FDOT approved users as required by the Department's data retention policies
- Ability to timestamp all SWZ Central Processor collected data along with PCMS and VSL sign messages generated
- Clear electronic Operations Manual available to users

4.2 SWZ Communication and CAV Plan

As noted in other sections, many SWZ roadside devices require real-time communication to function as intended. The SWZ Communication and CAV Plan will use Point-to-Point/Multipoint (P2P, P2M) wireless, Cellular, or connected vehicle communication technologies. SWZ communication considerations include:

- P2P/P2M to transmit data from intrusion detectors and vehicle entering roadway detectors to workers wearing wearable technologies and/or to roadside active warning devices. P2P/P2M communication layout must identify and mitigate any potential line of sight or frequency interference issues.
- Cellular communication to send roadside data to:
  - SWZ Central Processor
  - An FDOT RTMC
- Connected Vehicle communication to:
  - Optional to P2P/P2M for transmission of data between intrusion detection and wearable devices/alarms
  - Transmit data between roadside equipment and RSU
  - Transmit data between vehicle-mounted equipment and RSU
  - Transmit data between RSU and On-Board Units (OBU)

For current wireless communication security protocol and connected vehicle security credentialing management system requirements, contact FDOT's CAV Program Manager in State Traffic Engineering and Operations Office.

4.3 SWZ Training

Training is recommended for SWZ designers, installers, managers, and maintainers. Training is often specific to the SWZ technologies provided by the device manufacturer or vendor. For this reason, SWZ procurement documents must consider the need for training as a part of project delivery. **Table 9** lists possible SWZ training objectives for various SWZ stakeholders. Training needs should be addressed in the ConOps, PSEMP, and procurement documents, as appropriate.

Table 9: Possible SWZ Training Objectives

SWZ Stakeholders	Training Objectives
Designers, TTCP Developers	• Selection of SWZ strategies • SWZ Developmental Specifications • SWZ DDC • SWZ Developmental Standard Plan • Incorporation of SWZ into TTCP • SWZ Management and Operations Plan development • Systems engineering for SWZ • Requirements development for design/build projects
State and local traffic law enforcement officers	• Enforcement expectations, practices • Speed harmonization concept, current speed limits

SWZ Stakeholders	Training Objectives
Contractor traffic management superintendent and personnel	• Installation, setup, and configuration expectations • Installation verification testing • Installation monitoring and oversight • Installation maintenance
Construction Engineers and Inspectors	• Installation inspection • Installation verification testing oversight • Installation monitoring and oversight
RTMC Managers and Operators	• Monitoring SWZ with permanent ITS and temporary ITS equipment and communication • Monitoring SWZ through Internet portals • Managing DSH applications, setting speed limits

Chapter 5: SWZ Public Information Plan

When using SWZ strategies and technologies in the TTCP, the Public Information Plan (PIP) described in ***FDM 240.4*** should address SWZ elements included in the project. The PIP should communicate to the traveling public the intent, features, and duration of smart work zone strategies planned for the project. The PIP should take into consideration needs relative to multiple trip types such as daily commuters and tourists.