INDIANA DEPARTMENT OF TRANSPORTATION

Driving Indiana's Economic Growth

Design Memorandum No. 22-16

August 4, 2022

TO: **All Design, Operations, and District Personnel, and Consultants**

FROM: ***/s/Ed Cox***
Ed Cox
Director, ITS Engineering
Traffic Management Division

SUBJECT: **Intelligent Transportation Systems (ITS) Update**

REVISES: ***Indiana Design Manual*** **(IDM), Chapter 502, Sections 502-5.0 502-5.01(01) thru 502-5.01(03), 502-5.01(04) and 502-5.01(05) (new), 502-5.02 (deleted), 502-5.03(01), thru 502-5.03(04) , 502-5.03(05) thru 502-5.03(08)(new) , 502-5.04 thru 502-5.04(04), 502-5.04(05) (deleted), 502-5.04(06) thru 502-5.04(09) , 502-5.04(10) and 502-5.04(11) (new), 502-5.05 thru 502-5.05(02) deleted**

Figures 502-5A, 502-5B, 502-5C, 502-5D, 502-5E, 502-5F (deleted)

EFFECTIVE: **Stage 3 submittals on or after September 1st, 2022**

This memo updates the Intelligent Transportation Systems (ITS) subsection in Chapter 502 of the *Indiana Design Manual* (IDM). This subsection of the IDM has not been updated since the original 2013 design manual was published. These revisions are consistent with the current practices of the Traffic Management Division as well as current IDM standards.

Technologies and installations no longer used by the Department have been removed, including non-invasive detection (often called "microloops"), Highway Advisory Radio (HAR), battery-powered sites, Data Collection Sites (DCS), existing cellular communication tower-based sites, and Aires Field Processors (AFP). Figures referencing technologies and processes no longer in use have been removed. Figures showing Virtual-Weigh-in-Motion (VWIM) details have been removed and are being revised into a new set of standard drawings that are forthcoming. New technologies and installations have been added, including IP-based communication protocols, wireless magnetometers, monopoles, third-party internet service providers, Roadside Weather Information Systems (RWIS), and Truck Parking Information Management System (TPIMS).

References to the former *ITS Strategic Deployment Plan* have been removed. Site safety and accessibility standards have been established. Networking guidance has been simplified and updated to IP-based communication protocols. Communication design standards have been updated, including adding additional fiber optic cable network design standards.

For questions related to this design memo please contact Drew Sorenson, ITS Operations Engineer, at dsorenson@indot.in.gov.

IDM Revision Overview

IDM Section	Title	Revision
502-5.01	General	The ITS program description has been reduced and generalized to reflect the more expansive scope of INDOT ITS applications.
502-5.01(01)	Purpose of ITS	Revised to clarify and update purposes to reflect current INDOT ITS applications.
502-5.01(02)	National and Regional Architecture	Revised to remove reference to *INDOT Traffic Management Strategic Deployment Plan.*
502-5.01(03)	Coordination with Traffic Management Centers	Section title was revised to Coordination with Traffic Management Division.
502-5.01(04)	Site, Plan, and Document Reviews	Section title was revised to ITS Project Milestones. New content regarding stage reviews.
502-5.01(05)	Viewshed Analysis and Survey	New content regarding verification of camera viewing areas
502-5.02	Use of the ITS Strategic Deployment Plan	This section was deleted.
502-5.03	Design Criteria	Section title was revised to General Site Design Criteria. Broad design criteria were moved to corresponding sections. References to *Strategic Deployment Plan* and solar sites were deleted.
502-5.03(01)	ITS Infrastructure Component Locations	Section title was revised to General Site Selection and Safety. References to *Strategic Deployment Plan* were deleted. Additional guidance was added for site selection, including clarifying site safety and accessibility requirements.
502-5.03(02)	Electrical Service Points	Clarification was added that all sites must be powered by AC electrical service. Clarification was added about the distance between the meter and utility connection point. Guidance was added about phase-taping overhead service wires. Guidance for additional service disconnects was updated and expanded.

IDM Section	Title	Revision
502-5.03(03)	ITS Cabinet	The use cases for free-standing and pole-mounted cabinets were clarified. Tower-mounted cabinets were deleted. Cabinet placement guidance for Travel Time Sign (TTS) and TPIMS signs was added.
502-5.03(04)	Support Structure	Guidance for monopoles and DMS cantilever structures was added. Guidance for existing cellular communication towers was deleted. Guidance for self-supporting towers was updated.
502-5.04	Devices	Section title was revised to Field Devices. Discussion of device groups was deleted.
502-5.04(01)	Overhead Dynamic Message Signs (DMS)	Section title was revised to account for ground and median-mounted DMS installations. The description was updated. References to IMUTD DMS location guidance were added. Reference to *Strategic Deployment Plan* was deleted. Access ladder location guidance was added. Network connectivity guidance was simplified and moved to the Field Devices section.
502-5.04(02)	Travel Time Sign (TTS)	Location guidance was added to reference *IMUTCD*. Reference to *Strategic Deployment Plan* was deleted. Guidance for sign placement for maintenance access was added.
502-5.04(03)	Closed Circuit TV (CCTV) Camera System	Camera connection cables were updated to CAT6 POE. Support structure guidance was updated to include monopoles and remove existing cellular communication towers.
502-5.04(04)	Detection	Non-invasive detector guidance was deleted. Side-fire microwave detector equipment requirements were updated. Wireless magnetometer detector guidance was added. Guidance for solar-powered detection sites was deleted.
502-5.04(05)	Field Controller	The section was deleted. Its content was updated and moved to item 502-5.03(08) Communication.
502-5.04(06)	Communication	The section was deleted, the contet was moved to section 502-5.03(08) Communication. Fiber optic guidance was updated by eliminating CDPs, renaming GBICs to SFPs, adding guidance on SFP bandwidth requirements, adding an item for communication shelters, and updating guidance for cable route marking and fiber optic locator post placement. Cellular Data Connection and Third-Party Internet Service Provider (ISP) were added.

IDM Section	Title	Revision
502-5.04(07)	ITS Handhole and Conduit	The section was deleted and its content was broken down into two separate sections 502-5.03(05) ITS Handhole and 502-5.03(07) Conduit. Guidance was added that high-voltage and low-voltage cables may not terminate in the same handhole. Guidance for handhole labeling was updated. A reference to the National Electric Code (NEC) was added for conduit sizing. Guidance was added that high-voltage and low-voltage cables may not be located in the same conduit. Guidance for conduit crossing features at bridges was added. Section 502-5.03(06) ITS Vaults was added.
502-5.04(08)	Closed Circuit TV Site Requirements	The section was deleted and its contents were moved to Sections 502-5.04(03) CCTV Camera System and 502-5.03(01) General Site Selection and Safety. Driveway guidance was expanded to include radius design details, a reference to Section 42-2.0 for sight distance requirements, and a reference to Chapter 203 for hydraulic analysis requirements.
502-5.04(09)	Traffic Monitoring System	References to Data Collection Sites (DCS) were deleted. The design criteria item was updated to include Automatic Traffic Recorder (ATR). Guidance on allowable pavement types was clarified and guidance for continuously reinforced concrete (CRC) pavement was added. Guidance for communication was updated. Guidance for drainage pits was deleted. Axle detection guidance was updated.
502-5.05	Plan Development Procedure	The section was deleted.
502-5.05(01)	Site Reviews	The section was deleted and moved to section 502-5.01(04) Site, Plan, and Document Reviews. Office and field categories were combined into one list of requirements at all stages of the design process. Design process milestones were updated to reflect the current naming convention.
502-5.05(02)	Bucket Truck Survey	The section was deleted and moved to Section 502-5.01(05) Viewshed Analysis and Survey. Requirements for viewshed analysis and survey were updated. Guidance was added to allow a UAS to be used to perform a viewshed survey.
502-5.06	Supplemental References	A list of supplemental design documents was added to provide designers with additional resources that may be helpful during the design process.

IDM Section	Title	Revision
Figures 502-5A, 502-5B, 502-5C, 502-5D, 502-5E, 502-5F were deleted.		

502-5.0 INTELLIGENT TRANSPORTATION SYSTEM (ITS) [REV. AUG. 2022]

502-5.01 General [Rev. Aug. 2022]

The Federal Highway Administration (FHWA) defines ITS in the Final Federal Rule (23 CFR 940) on ITS Architecture and Standards Conformity (Final Rule) as, "electronics, communications, or information processing used singly or in combination to improve the efficiency or safety of a surface transportation system." The full text of FFR 23 CFR 940 can be found at https://www.fhwa.dot.gov/legsregs/directives/fapg/cfr0940.htm. ITS is the physical infrastructure that supports a variety of traffic management strategies. For example, closed-circuit television (CCTV) roadway surveillance supports the dispatch of Hoosier Helpers, the Department's Freeway Safety Patrol initiative.

502-5.01(01) Purpose of ITS [Rev. Aug. 2022]

1. Provide Information for the Driving Public. ITS gathers and distributes information to the traveling public through means such as roadside messaging and our online CARS 511 data portal that enables them to make informed decisions. The CARS 511 website can be found at https://511.in.org.

2. Improve Roadway Safety. ITS gathers information that helps emergency response personnel identify and respond to traffic incidents to restore traffic flow as quickly as possible improving the safety of the roadway system. Providing the traveling public with better information can help reduce congestion and reduce the likelihood of back-of-queue crashes.

3. Reduce Environmental Impacts. ITS reduces congestion and helps keep the average arterial speed close to the speed limit which facilitates the lowering of emissions from idling automobile engines.

4. Collect Traffic Data. ITS gathers traffic information for research, operational, and planning needs.

502-5.01(02) National And Regional Architecture [Rev. Aug. 2022]

On January 8, 2001, the Final Federal Rule (23 CFR 940) on ITS Architecture and Standards Conformity (Final Rule) and the Final Policy on Architecture and Standards Conformity (Final Policy) were enacted by the FHWA and Federal Transit Administration (FTA) respectively. The Final Rule/Final Policy ensures that an ITS project carried out using funds from the Highway Trust Fund including the Mass Transit Account is in accordance with the National ITS Architecture and applicable ITS standards. This will be

accomplished through the development of regional ITS architectures and the use of a systems engineering process for ITS project development.

1. FHWA Rule on ITS Architecture and Standards Conformity. This rule is provided to ensure that an ITS project carried out using funds made available from the Highway Trust Fund is in accordance with the National ITS Architecture and applicable standards.

2. FTA Policy on ITS Architecture and Standards Conformity. This policy is provided to ensure that an ITS project carried out using Mass Transit Funds from the Highway Trust Fund is in accordance with the National ITS Architecture and applicable standards.

Both of these documents appear at http://www.iteris.com/itsarch.

Each ITS project involving federal funds must be in accordance with the National ITS Architecture and the Systems Engineering Process as defined in 23 CFR 940. The designer should work with the system owner to ensure all system engineering requirements are met. For INDOT projects the designer's role in the systems engineering process will be defined in their contract. For INDOT projects the designer's role in alternative development and cost-benefit analysis will be defined in their contract. A Systems Engineering form should be completed and submitted to the FHWA for review and approval on each federally-funded non-INDOT ITS project. Contact INDOT ITS to obtain this form. For more information about the systems engineering process, refer to the FHWA Systems Engineering and ITS Project Development Website at https://ops.fhwa.dot.gov/plan4ops/sys_engineering.htm.

The Systems Engineering form should be submitted to FHWA for review subsequent to project Notice to Proceed and prior to preliminary plans development. In conjunction with final plans submission, the form should be resubmitted, including the most current project revisions and Department review comments.

The National ITS Architecture can be accessed via http://www.iteris.com/itsarch/. For Statewide ITS Architecture, contact the Department. Regional ITS Architectures appear on the website of the state's Metropolitan Planning Organizations (MPOs).

502-5.01(03) Coordination with Traffic Management Division [Rev. Aug. 2022]

For both new ITS construction and ITS relocation projects, the designer should coordinate with INDOT ITS regarding the maintenance of existing ITS equipment such as dynamic message signs, sensors, and cameras during construction.

502-5.01(04) ITS Project Milestones [New Aug. 2022]

1. Scoping. During the scoping process, scoping teams should coordinate with INDOT ITS for the following purposes:

   a) To capture the cost and scope of required ITS facility relocations or replacements in the project scope and scoping cost estimate.
   b) To allow potential bundling of new ITS construction with other nearby projects for MOT and economies of scale savings

   This coordination does not replace the required coordination with department owned lines described in Chapter 104.

2. Preliminary Field Check. The designer and the Department should discuss information including constructability and communication issues for each proposed site and adjust locations if necessary. The designer should notify INDOT ITS of this an all other field activities to enable INDOT ITS representatives to participate.

3. Stage 1. The designer should provide the high-level, conceptual ITS design for the project including device locations and preliminary communication network plan.

4. Stage 2. The designer should provide preliminary cost estimate and special provisions as well as plans of the following:

   a) site locations;
   b) communication information;
   c) constructability requirements;
   d) driveway or fencing;
   e) drainage;
   f) grounding; and electrical service connections and utility coordination.

5. Stage 3. The designer should provide the final design package, which should include the following:

   a) title and index sheets;
   b) plans sheets;
   c) site details;
   d) construction details including but not limited to foundations, grounding, driveways, pipes, fences and gates;
   e) cabinet details;
   f) electrical and communication schematics;
   g) electrical wiring diagrams;
   h) quantities;

i) design calculations including but not limited to drainage, communications line of sight, driveways, guardrail, voltage drops;
j) cost estimate; and
k) special provisions.

502-5.01(05) Viewshed Analysis and Survey [New Aug. 2022]

During the design process after preliminary site selection and prior to final site selection approval, the designer should verify the viewing areas of new cameras and the line of sight for the wireless communication by performing a viewshed analysis. A viewshed survey may be required if necessary and feasible. A bucket truck or unmanned aerial system (UAS) may be used to perform the viewshed survey. The designer should provide equipment and personnel if INDOT ITS determines a viewshed survey is warranted.

502-5.02 Use of the ITS Strategic Deployment Plan [Del. Aug. 2022]

502-5.03 Design Criteria [Rev. Aug. 2022]

Elements including to but not limited to drainage, slopes, clear zone, and access to electrical power should be considered in the site selection process. Final component locations require approval by INDOT ITS. Specific site locations should be called out in the plans with approximate mile markers in addition to project stationing. Where feasible, ITS devices should be collocated to reduce cost of providing power and communications.

502-5.03(01) General Site Selection and Safety [Rev. Aug. 2022]

Each site should be designed to accommodate easy and safe access for construction and maintenance operations. Each site should be accessible from Department maintained right-of-way and should not be located behind sound barrier. A minimum of 12 ft of lateral clearance between the edge of a traveled lane and the nearest impassible obstacle such as guardrail, barrier wall, or unrecoverable shoulder is required for maintenance personnel to park on the shoulder and perform maintenance safely. If the design does not provide this minimum clearance, the designer should provide documentation justifying their decision and identifying what alternatives were evaluated, such as an aggregate driveway or bumping out guardrail.

The radius and width of a driveway entrance should accommodate a single-unit (SU) truck as defined in Section 46-12.0. The driveway should be designed such that an SU truck can turn around in the driveway before reentering traffic. Sight distance for the driveway should comply with Section 42-2.0. If a driveway will impact existing drainage, a hydraulic analysis should be performed per Chapter 203. A driveway is required under any of the following conditions:

1. Site components are located more than 50 feet from the edge of the road or existing parking area
2. A drainage feature between the shoulder and the site is deeper than 4 feet and is expected to hold water or is otherwise unsafe to cross on foot

The decision to provide a driveway should be made on a site-by-site basis and driveway locations must be approved by INDOT ITS.

All ITS infrastructure, device, and support structure placement should comply with guidance in Chapter 49 concerning the clear zone and the treatment of any obstructions therein.

502-5.03(02) Electrical Service Points [Rev. Aug. 2022]

All INDOT ITS sites should be powered by AC electrical service.

1. Utility Coordination. The designer should coordinate with the local power company and provide the following information.

    a. Pole number from which power will be delivered to the new service point.

    b. Additional service connection fees. The power company is responsible for providing the service connection to the right-of-way line. If the local power company requires an additional fee to bring power to the right-of-way line, it should submit plans and an estimate of related costs to the designer for approval by the Department. Payment for each connection should be included in the cost of the individual service point.

    Utility coordination correspondence including plans and contact information should be included in the project documentation. Additional service point related fees should be included in the average service point unit price in the contract Engineer's Estimate. Additional location-specific service point-related fees should be described in a unique special provision.

2. Design Considerations. Each ITS site should be metered. The designer should coordinate with the local power company to determine the appropriate overhead or underground service point location. The meter should be located within 15 feet of the utility connection point, or as close to the utility connection point as can be located on state right-of-way.

    For overhead service, all wires between the weather head and the service meter should be UV-resistant, black, and phase-taped.

Each ITS site requires a single-phase, three-wire system, 2 hot lines and 1 neutral plus ground electrical service of 120/240VAC 100 A. Power wires (black, red), and Neutral (white) should be #2 copper. Ground wire should be green #6 copper.

The service point should be specified on the plans as having a multi-position, 100 A, 600 V, main circuit breaker with separate branch circuit breakers rated for the current consumption of each field device but no less than 30 A. A NEMA 3R enclosure should be specified. The service point should be placed on a steel H-frame. Contact INDOT ITS for H-frame details.

The designer should verify the voltage drop does not exceed 7% across a circuit. If the voltage drop is found to exceed 7% across a circuit, the power wire should be increased as needed to meet voltage drop requirements. Buck-boost transformers should not be used without prior INDOT ITS approval.

An additional service disconnect is required if one of the following conditions exist at the project site:

a) when the service point is on the same side of the road as the cabinet and is more than 150 ft from the cabinet or not clearly visible from the cabinet;

b) when the service point and the cabinet are on the opposite sides of the roadway; or

c) when an obstruction exists between the service point and the cabinet that prevents immediate access by maintenance personnel including but not limited to:

    1) Fencing
    2) Steep slope/drop off
    3) Drainage ditch expected to hold water
    4) Overgrowth
    5) Sound wall

If an additional service disconnect is required, the designer should specify a 2-pole disconnect and show it located within 30 ft of the cabinet. Service disconnect should be placed on a steel H-frame. Contact INDOT ITS for H-frame details.

502-5.03(03) ITS Cabinet [Rev. Aug. 2022]

1. General. An ITS control cabinet provides a protected space for communication and control equipment needed to operate ITS installations. A free-standing, base-mounted control cabinet should be used. A pole-mounted cabinet may be used for monopole closed circuit television (CCTV) camera installations. If the site location does not allow for a free-standing, base-mounted cabinet, a pole-mounted control cabinet can be considered with INDOT ITS approval. A single cabinet should be provided when collocating multiple ITS devices at the same site provided all necessary communication and control equipment for each device can fit in the same cabinet.

2. Installation Requirements. Each cabinet should be installed in a safe, easily accessible location. A technician should be able to safely observe the situation on the roadway while troubleshooting or repairing equipment. Cabinets for Travel Time Signs (TTS) and Truck Parking Information Management System (TPIMS) Truck Parking Information Signs should be located so technicians can observe the front of the sign while working on the cabinet. Traffic Monitoring System cabinets should be oriented so technicians can observe traffic passing over the sensor array while working at the cabinet.

    a. Free-Standing ITS Control Cabinet. The cabinet should be installed on the standard foundation. For cabinet foundation details, see the INDOT *Standard Drawings*.

    b. Pole-Mounted Control Cabinet. The top of the cabinet should be 6 feet above ground level at the base of the pole.

502-5.03(04) Support Structure [Rev. Aug. 2022]

The following support structures should be used for ITS equipment.

1. Monopole. A monopole is typically used to support CCTV cameras and traffic detection hardware for roadway surveillance. The monopole height should be based on the required elevation of the attached equipment

    The contractor shall provide structural designs, calculations, and engineering drawings signed and sealed by a professional engineer registered in the state of Indiana for each new monopole and monopole foundation. The foundation design should be based on the site-specific soil boring results and should consider the existing and proposed site conditions as shown on the plans for each individual monopole site. A monopole foundation should not interfere with natural or constructed drainage or runoff.

2. Standard Light Pole. A standard roadway light pole should be used for mounting traffic detection devices and associated communication equipment. The top of the pole should not extend more than 10 ft above the height of the equipment.

3. Dynamic Message Sign (DMS) Box Truss. A box truss should be used to support overhead DMS. Box truss structure design and box truss foundation design should be as shown on the INDOT *Standard Drawings*.

4. DMS Cantilever. A DMS cantilever structure should be used to support a ground or median-mounted Dynamic Message Sign. Contact INDOT ITS for DMS cantilever structure and foundation details.

5. Cantilever. Cantilever TTS supports and foundations should be as shown on the INDOT *Standard Drawings*.

6. Self-Supporting Tower. A self-supporting tower is used to support CCTV cameras and traffic detector hardware for roadway surveillance and additional communications equipment that cannot be accommodated on other support structure types. Self-supporting towers should only be considered for installations requiring a structure more than 100 ft in height or installations required to support communications equipment that cannot be accommodated on other support structure types.

   The tower height should be determined based on the required elevation of the tower equipment such that the top of the tower does not extend more than 10 ft above the height of the equipment.

   The tower materials should comply with the Lighting section of the *Standard Specifications*. The contractor shall provide structural designs, calculations, and engineering drawings signed and sealed by a professional engineer registered in the state of Indiana for each new tower and tower foundation. The foundation design should be based on the site-specific soil boring results and should consider the existing and proposed site conditions as shown on the plans for each individual tower site. A tower foundation should not interfere with natural or constructed drainage or runoff. Each tower should be designed in accordance with ANSI requirements.

502-5.03(05) ITS Handhole [New Aug. 2022]

Handholes provide access to underground conduit and wire without having to mobilize excavation equipment. Handholes should be installed at every change in direction of underground conduit. Handholes should not be located in the traveled way or paved shoulder. ITS Handholes should be type I (concrete) as shown in the *Standard Drawings* for traffic signals. High-voltage power distribution cables should not terminate in the same handhole as low-voltage power cables or fiber optic cable. Handholes should be labeled as follows:

1. "Traffic Management Power" – for handholes used for high-voltage power distribution cables
2. "Traffic Management Fiber" – for handholes used for fiber optic cable
3. "Traffic Management System" – for all other handholes

502-5.03(06) ITS Vault [New Aug. 2022]

Vaults provide a protected space for fiber optic cable splices enclosures and allow access to fiber optic cable splice enclosures. Vaults should be installed at all planned fiber optic splice location and otherwise every 2,000 ft along backbone fiber optic cable. Contact INDOT ITS for ITS Vault details.

502-5.03(07) Conduit [New Aug. 2022]

Conduit provides a protected space for power and communication wires and fiber optic cable. Unless otherwise directed by INDOT ITS, the designer should specify Schedule 80 HDPE or PVC conduit for underground applications and galvanized steel for above ground. Conduit size should be selected based on the number and diameter of cables in the conduit per National Electrical Code (NEC) requirements, but should not be less than 1.25 in. High-voltage power distribution cables should not be in the same conduit as low-voltage power cables or fiber optic cable.

When a conduit run will cross a feature also crossed by a Department-owned bridge such as a body of water, railroad, or roadway, the conduit should be bored under the feature. If boring under the feature is infeasible, the conduit can be attached to the bridge with INDOT ITS approval.

502-5.03(08) Communication [New Aug. 2022]

The purpose of the communication network is to provide stable unrestricted data flow between field sites and Traffic Management Centers. Means of communication should be selected based on the following local conditions:

1. Nearby existing communications infrastructure
2. Project funding
3. Bandwidth requirements
4. Distance between communicating sites
5. Line of sight availability

All field sites require a field ethernet switch to combine all outgoing communications into a single stream and route all incoming communications to the appropriate device. Most new ITS field devices use IP protocols and can communicate directly with the ethernet switch without the need for a field processor. If a field device requires a field processor, contact INDOT ITS for further direction.

The means of communication between field sites and the Traffic Management Centers are described as follows:

1. Fiber Optic Cable. Fiber optic cable is the most reliable and stable form of communication and provides the greatest bandwidth capacity and should be the first communication option considered. If fiber optic cable is not feasible, the remaining communication options may be considered.

   A fiber optic system connects a field site to the TMC through a network of physical infrastructure consisting of the following:

   a. Cable. Cable should be armored and contain fiberglass strands, or fibers, in increments of 12. One field site requires two fibers: one for ingoing and one for outgoing data streams. Four fibers per field site are required if redundancy is specified. Connecting remote sites to the main communication network should be accomplished by means of providing dedicated fibers connecting each remote site to the nearest communication shelter, and to the nearest communication shelter in either direction if redundancy is specified. The number of fibers required is dependent on the number of field sites on each backbone fiber run.

   b. Backbone Fiber. High strand count fiber that provides the physical infrastructure for data to be transmitted from field sites to the TMCs, often via communication shelters along the way. Backbone fiber runs should have a minimum of 96 strands of fiber.

c. Drop Cable. Lower strand count fiber that is spliced to the backbone fiber to interface between the backbone fiber optic cable and a field site. The proper wavelength and termination means should be selected and shown on the plans.

d. Patch Panel. Termination points for individual fibers. The size of the patch panel should be determined by the number of fibers being terminated.

e. Patch Cable. Connects fibers from their port on a patch panel to a port on a switch

f. Small Form Pluggable Transceiver (SFP). This is required at the switches at both ends of each active fiber strand to convert electronic signals into pulses of light, amplify them, and at the other end convert pulses of light back to the electronic signals. SFPs should be selected for each connection based on the distance between the links and the bandwidth required. 1 gigabit SFPs should be specified for communication to and from individual sites and 10 gigabit SFPs should be specified for multi-link trunking (MLT) communication between communication shelters.

g. Communication Shelter. A small climate-controlled outbuilding typically positioned at the confluence of two or more runs of backbone fiber optic cable containing core ethernet switches and fiber optic patch panels to facilitate the flow of data to and from the TMCs. For shelter equipment details and specifications, contact INDOT ITS

h. Installation. Appropriate means are as follows:

1) Fiber optic cable should be placed in conduit.

2) Fiber optic cable should be installed beneath the outside shoulder or median. If installed beneath the outside shoulder, the cable should be placed as far from the edge of the road as possible. Fiber optic cable should never be installed behind sound barrier wall. Where cable is to be installed beneath the median, the FHWA must be contacted for approval.

3) Splices in the fiber optic backbone should be used where ITS sites connect to backbone fiber or where new backbone fiber ties into existing backbone fiber. The number of splice locations along the backbone fiber should be limited as much as possible to preserve signal strength.

4) New splices should not be introduced when repairing or relocating existing fiber optic cable backbone. Fiber should be replaced between existing splices.

5) After installation, fiber optic cable should be located with copper wire or other industry-accepted method as approved by INDOT ITS.

6) Fiber optic locator posts should be placed at each vault. If backbone fiber optic cable crosses a divided highway, a locator post should be placed on either side of the crossing.

7) Spare conduits should be provided along backbone fiber runs for future system expansion. 2 spare conduits should be specified.

8) Cable route marking should be identified via flexible cable markers. Flexible cable duct markers should be spaced every 250 ft along straight segments, provided at every fiber optic cable handhole and vault, provided at every significant change in direction, and placed such that the proceeding markers can be seen from any marker.

9) Networking. Each new component or group of components should be organized to allow accommodation of the new components into the existing network. All networking equipment should be compatible with the existing network infrastructure. INDOT ITS will provide a schedule of IP addresses. The naming convention should be provided for all new components in accordance with Department requirements.

2. Cellular Data Connection. This method of communication can be used if INDOT ITS fiber optic is not available or feasible. A cellular data connection is possible anywhere there is cellular data service. A cellular data connection consists of a cellular modem and approved antenna to be installed at each site. Cellular modem and equipment can be found on the ITS Qualified Products List. INDOT ITS will provide configuration settings and IP structure.

3. Wireless. This method of communication can be used if INDOT ITS fiber optic is not available or feasible. A wireless application is possible where there are no obstructions to the line of sight between the ends of the link, and the recommended hardware is capable of producing a signal strong enough to be received by each end

of the proposed link. Wireless hardware that is compatible with existing network equipment should be selected.

A frequency band in compliance with FCC requirements should be selected. New hardware should be determined to be compatible with existing. The 5.4 - 5.8 GHz band is utilized for licensed radio applications. The 2.4 GHz frequency is utilized for unlicensed radio applications. Depending on bandwidth capability, wireless devices are classified as High Speed, approximately 50 Mbps and higher throughput, or Low Speed, 10 to 40 Mbps throughput, used as follows:

a. High Speed Radio is used to connect video streams with one or more sources to backbone nodes.

b. Low Speed Radio is used to connect vehicle detection sites to the camera towers and to receive information for DMSs and TTSs.

4. Hybrid. This method of communication can be used if INDOT ITS fiber optic is not available or feasible. Hybrid communication combines the fiber optic and wireless systems described above. CCTV sites, or cluster hubs, are connected with fiber optic cable to create a local back-bone structure. Individual vehicle detection sites, DMSs, TTSs, and Traffic Monitoring Systems located in proximity to a cluster hub communicate wirelessly to the base unit located at the hub.

Third Party Internet Service Provider (ISP). This method of communication can be used if INDOT ITS fiber optic is not available or feasible. This method of communication provides a wired or wireless connection from a CCTV site or cluster hub into a private carrier's network infrastructure. These carriers can provide a secure virtual private network/VPN-style tunnel connectivity from the remote site into the TMC data center. Such examples include traditional cable TV telephone operators which can provide business-class high speed internet points of presence located within serviceable distance to the cluster hub.

502-5.04 Field Devices [Rev. Aug. 2022]

Some of the devices used in an ITS System are proprietary. To use them on an FHWA-funded project, a Public Interest Finding (PIF) form should be submitted and approved by the Department and FHWA. Some devices have achieved programmatic approval and do not require a separate PIF filing. A list of such devices appears at http://www.in.gov/indot/2684.htm under Programmatic Proprietary Material Approvals for ITS.

All equipment should be compatible with existing INDOT ITS network and communication processes and protocols. Contact INDOT ITS for questions about equipment compatibility.

502-5.04(01) Dynamic Message Signs (DMS) [Rev. Aug. 2022]

This device is used to convey information to the traveling public about prevailing road and traffic conditions and important events. DMS locations should be selected based on availability of electrical service and the guidance provided in the *IMUTCD*. All planned DMS locations must be approved by INDOT ITS.

DMSs do not require ITS cabinets. The communication and control equipment for the sign are contained inside the DMS enclosure. For electrical service and disconnect placement at a DMS, the base of the ladder should be considered the cabinet.

For gantry mounted DMSs, the access ladder should be on the outside (non-median) side of the road. See the INDOT *Standard Drawings* for DMS details.

502-5.04(02) Travel Time Sign (TTS) [Rev. Aug. 2022]

This device is used to convey near real-time downstream travel times to the traveling public.

1. Location. Each TTS location should comply with guidance provided in the *IMUTCD* and must be approved by INDOT ITS.

2. Equipment. TTS should consist of a standard panel sign with a white legend and border on blue background with information including the distance and current travel time to downstream destinations determined by INDOT ITS. The travel time should be displayed on a dynamic LED information panel, or panels, inserted in the panel sign.

    a. The panel sign should be in accordance with the INDOT *Standard Specifications* and *IMUTCD* requirements.

    b. The Travel Time Sign Information Panel (TTSIP) should be capable of communicating with the ATMS network using accepted protocols. The TTSIP assembly should display 3 digits, sized in accordance with *IMUTCD* requirements.

2. Support Structure. The TTS should be installed on a standard overhead sign structure, selected according to overall sign area. The TTS should not be located over travelled lanes so maintenance activities can be performed without closing lanes. The TTS can be located over paved shoulders.

502-5.04(03) Closed Circuit TV (CCTV) Camera System [Rev. Aug. 2022]

This system provides live video to TMC personnel or selected external recipients as determined by the Department. The CCTV cameras should be pan/tilt/zoom capable.

An operator receives real-time video streams and manages control of the camera views. Videos are used to monitor and analyze roadway incidents and to facilitate Hoosier Helper and other emergency response deployment. Media outlets have access to delayed video streams, but they do not have control over the cameras. CCTV system specifics are described below.

1. Location. The designer should select locations given the following considerations. All locations of planned CCTV installations must be approved by INDOT ITS

    a. Each camera should provide a clear overview of the longest possible segment of roadway. Locations should be identified where more than one camera is needed at a tower site to provide necessary functionality.
    b. The distance between the CCTV tower site and overhead electrical lines should be greater than the height of the support structure, with a preferred distance of more than 150 ft.

2. Camera and Interface Equipment. This consists of the central camera unit, weatherproof protective housing with clear lens on the bottom, interface unit, and two CAT6 ethernet cables, a main and a spare, to be powered by power-over-ethernet (POE).

3. Camera Lowering Device (CLD). The camera lowering device should include a permanent winch with handle and a 1-1/8-in. socket. The CLD should include a guide wire to direct the camera while it is being lowered. This wire should be secured to the bottom of the support structure while the CLD is not in use. The CLD should provide for the guide wire to be positioned at the appropriate angle to the tower leg while the CLD is in the working position.

4. Support Structure. A monopole or self-supporting tower should be used as the support structure. A high-mast tower or light pole may be used when:

   a. One of the structures exists and is available for use in the vicinity of the selected location; and
   b. It is unsuitable to build an additional structure at the selected location.

502-5.04 (04) Detection [Rev. Aug. 2022]

Detection is used by the Department to monitor real-time traffic characteristics. The Department uses two vehicle detection systems: side-fire microwave and wireless magnetometers. Detectors should be located to detect traffic volume and vehicle speeds on the lanes of a multi-lane highway and on the on-ramps at a system (freeway-to-freeway) interchange. The two detection alternatives are described below.

1. Side-Fire Microwave Detector. Each site provides vehicle speed and volume data from the detector units, mounted above and adjacent to the roadway. Each detector unit can obtain data from 4 to 10 lanes of traffic.

   a. Location. Each specific location should be verified based on the following considerations:

      1) Traffic flow is consistent. Vehicles do not change lanes often.

      2) Control cabinet and detector should be safely accessible for maintenance.

      3) Pole-mounted detector assemblies should be located outside the clear zone or in areas protected by guardrail. Refer to manufacturer specifications for site-specific detector assembly setback distance and mounting height. If recommended height cannot be used due to pole height, detector unit should be mounted as high as possible within the range recommended by the manufacturer.

   b. Equipment. A detection unit, which includes a sequence generator/receiver, an ethernet based communication device, and a power supply with surge protection should be provided at each site.

c. Installation. A microwave detector should be installed adjacent to the roadway shoulder attached to an existing traffic or ITS structure where possible. If no existing structure is available, the microwave detector should be installed on a new support structure. The distance from the detector to the control cabinet, or communication cable length should not exceed the manufacturer's recommendations.

2. Wireless Magnetometer. Each site provides speed and volume data from probes cored into the pavement. Each lane has two probes spaced per the manufacturer's recommendations (typically 20 feet). The probes communicate wirelessly to an access point mounted on an ITS support structure which is connected to equipment inside the cabinet.

a. Location. Locations should be selected based on the following considerations:

1) Traffic flow is consistent. Vehicles do not change lanes often
2) Control cabinet and wireless access point should be safely accessible for maintenance
3) Pole-mounted assemblies should be located outside the clear zone or in areas protected by guardrail. Refer to manufacturer specifications for site-specific detector assembly setback distance and mounting height

b. Equipment. Pavement detector probes and a wireless access point. A wireless repeater may be required if the distance between probes and the wireless access point exceeds manufacturer's recommendations.

c. Installation. The wireless access point should be installed adjacent to the roadway shoulder attached to an existing ITS support structure where possible. If no existing structure is available, the wireless access point shall be installed on a new ITS support structure. Wireless repeaters may be installed on sign post or INDOT ITS approved equivalent.

502-5.04(05) Field Controller [Del. Aug. 2022]

502-5.04(06) Communication [Del. Aug. 2022]

502-5.04(07) ITS Handhole and Conduit [Del. Aug. 2022]

502-5.04(08) Closed Circuit TV Site Requirements [Del. Aug. 2022]

502-5.04(09) Traffic Monitoring System [Rev. Aug. 2022]

A traffic monitoring system consists of a Weigh-in-Motion (WIM) sensor, Automatic Traffic Recorder (ATR), or Virtual Weigh-in-Motion (VWIM) station.

The Code of Federal Requirements (23 CFR 500 Part B), available at http://ecfr.gpoaccess.gov/23CFR500, establishes a systematic process for the collection, analysis, summary, and retention of highway vehicular traffic data for a traffic monitoring system.

To comply with Federal requirements, VWIM, WIM, ATR, and DCS stations exist throughout the state. WIM and VWIM stations are also utilized as vehicle weight screening stations for police enforcement activities.

INDOT ITS should be contacted to determine if a traffic monitoring station is required.

INDOT ITS should be contacted to coordinate the design and review process. See the INDOT *Standard Drawings* for controller cabinet foundation details. Final layout drawings should be developed for review by INDOT ITS.

ATR, WIM, and VWIM design criteria are described as follows.

1. Physical Station Requirements. The designer should coordinate with INDOT ITS to determine where the station may be built within the project limits. The location should be in accordance with the following.

    a. The site should not be located within 1000 ft of an intersection or signal or within 500 ft of likely lane changes such as entrance and exit ramps.

    b. Horizontal Alignment. The horizontal curvature of the roadway for 200 ft in advance of and 100 ft beyond the system sensors should have a radius of not less than 5700 ft measured along the centerline of the roadway.

    c. Vertical Alignment. The grade of the roadway surface for 200 ft in advance of and 100 ft beyond of the sensors is not to be steeper than 2%.

    d. Cross Slope. The cross slope of the roadway surface for 200 ft in advance of and 100 ft beyond the sensors preferably should not be steeper than 3%. However, up to 4% is acceptable, but a grade steeper than 2% is allowable only in the leftmost travel lanes.

    e. Lane Width. Stations should not be placed where the lane width is less than 11.5 ft or greater than 14 ft.

2. Pavement. Adequate pavement structure and surface smoothness is required to ensure optimum performance of the sensors throughout the service life of the system. PCCP is preferred for all Traffic Monitoring System applications. If on a freeway or principal arterial highway, the station should be centered within a 450-ft segment of concrete pavement.

   a. HMA. HMA pavement is allowable in some instances for ATR stations but should be avoided for WIM or VWIM applications

   b. Reinforced PCCP. Reinforced pavement panels are required where roadway sensors are to be placed. The reinforcing bars should be placed in the lower half of the depth of pavement to minimize interference with loop detectors. In jointed PCCP where transverse joints are spaced at 18 ft, the reinforced PCCP section is within the center 50 ft of the 450-ft PCCP section.

      Continuously reinforced PCCP can be used with a traffic monitoring system only if the reinforcement is sufficiently below the pavement surface to accommodate sensor depth requirements and to not interfere with the loop detectors. Continuously reinforced PCCP at traffic monitoring system station should provide no less than 4 in. of cover from the top of reinforcing bars to the top of the pavement surface.

   c. Pavement Smoothness. The surface of the roadway a minimum of 200 ft in advance of and 100 ft beyond the system sensors should be tested prior to sensor installation. The designer should specify that the contractor use ASTM E 1318 Section 6.1.5.1 as the basis for testing. Test results must be submitted to INDOT ITS for approval prior to sensor installation.

   d. Pavement Transitions. Pavement should be free of transitions, such as HMA to PCCP or pavement to bridge abutment, at least 200 ft in advance of and 100 ft beyond a WIM or VWIM sensor array.

3. Electronic Equipment.

   a. System Controller/Recorder. A system controller/recorder is used with each Traffic Monitoring System. INDOT ITS should determine which type of system is to be specified, including the appropriate sensor array.

A controller/recorder should operate from 120 VAC, be accessible via IP-based communication systems, have an onboard ethernet connection, provide on-site data storage, be capable of generating a digital per vehicle data file in an approved format, and interface with roadway sensor arrays.

b. A communication method should be provided as discussed in section 502-5.05.

c. VWIM Imaging System. The purpose of the VWIM imaging system is to provide images of vehicles passing over the sensors so that they can be linked to the data record. These images should be able to be viewed in real time or stored for future use. Each VWIM imaging system consists of the following components:

1) camera, lens, and weatherproof enclosure;
2) pole and foundation. See the INDOT *Standard Specifications* and *Standard Drawings*;
3) illuminator system, infrared for night vision; and
4) Virtual Weigh Station (VWS or ICP) controller

The orientation of the camera(s) should be as recommended by the manufacturer and should be reviewed for approval by INDOT ITS.

4. Station Components. Contact INDOT ITS for typical drawings. Each station should include the following components:

a. Cabinet. The cabinet should be in accordance with Section 502-5.04(02) and the INDOT *Standard Drawings*. Traffic Monitoring Systems should have their own dedicated cabinet and should not share a cabinet with other ITS field devices.

b. Cabinet Foundation. The cabinet foundation should be in accordance with the INDOT *Standard Drawings.*

c. Traffic Monitoring Handhole, Ring and Cover. At least one handhole should be installed no farther than 10 ft from the foundation. See Section 502-5.04(04) for additional details.

d. Traffic Monitoring Detector Housing. This should be installed in accordance with the INDOT *Standard Drawings.*

e. Galvanized Steel and PVC Conduit. Galvanized steel and PVC conduit should be shown on the plans, should be in accordance with the INDOT *Standard Drawings* and should be labeled as follows:

1) PVC conduit of 2-in. diameter should be used between the traffic monitoring handhole and traffic monitoring detector housing, between the traffic monitoring handhole and camera pole, and from the service point to the camera pole.

2) PVC conduit of 3-in. diameter should be used between the traffic monitoring handhole and camera pole, and between all traffic monitoring handholes.

3) Galvanized steel conduit of 2-in. diameter should be used for each above-ground cable run.

4) High density polyethylene EHMW (HDPE) pipe may be used in place of PVC conduit in a trench, with the same diameter as the PVC conduit.

5) Flexible joints should be installed when transitioning from a buried conduit to conduit attached to a permanent structure to reduce vibration and movement damage.

f. Roadway Sensor Array. The sensors in use are as follows:

1) Presence Detection. Two round 6 ft loop detectors per lane should be used for presence detection and should be in accordance with the INDOT *Standard Drawings.*

2) Axle Detection. Piezo sensors should be used on ATR stations. Quartz or strain gauge axle sensors should be used on WIM and VWIM stations unless otherwise specified by INDOT ITS.

3) Temperature Sensor. One temperature sensor is required for each controller and should be in accordance with controller manufacturer recommendations.

Sensor placement should be such that saw slots are no closer than 2 ft to transverse pavement joints. Sensors should be offset from the leftmost lane to the right approximately 6.75 ft in a downstream direction. The designer should coordinate details with INDOT ITS.

502-5.04 (10) Roadside Weather Information System (RWIS) [New Aug. 2022]

A Roadside Weather Information System (RWIS) consists of atmospheric and in-pavement sensors that provide the Department with real-time information about atmospheric and road conditions. Where possible, RWIS sensors should be installed on other existing or planned ITS support structures, rather than on their own dedicated support structure. Contact INDOT ITS for sensor suite details.

502-5.04 (11) Truck Parking Information Management System (TPIMS) [New Aug. 2022]

The Truck Parking Information Management System (TPIMS) informs truck drivers of the number of available truck parking spaces at upcoming rest areas. TPIMS consists of the following:

1. Truck Parking Monitoring System. A truck parking monitoring system is used to monitor and verify the number of available truck parking spaces at a particular rest area, and consists of the following:

    a. Vehicle Detection. Vehicle detection should be provided at the entrance and exit of the truck parking area to provide an accurate real-time count of truck parking spaces available. Detection should be in accordance with Section 502-5.06(04).

    b. Overview CCTV Cameras. CCTV cameras should be in accordance with Section 502-5.06(03) and should be installed to provide complete coverage of the truck parking area to allow the Department to visually verify the number of available truck parking spaces. The designer should provide a viewshed analysis of proposed overview CCTV camera installations to demonstrate their height and location will allow a truck in any parking space to be uniquely identified if the lot is full and any landscaping is fully grown with full foliage. For this analysis, all trucks can be assumed to be 72 ft long, 13.5 ft tall, and 8.5 ft wide.

    c. ITS Cabinets. A pole-mounted ITS cabinet should be provided at the entry and exit vehicle detection points and each CCTV Camera location. ITS cabinets should be in accordance with 502-5.04(02).

d. Communication. One of the pole-mounted ITS cabinets at a CCTV camera location should be identified as the central communication cabinet. The central communication cabinet should contain all the necessary equipment to connect to the ITS network. All other cabinets should be connected to the central communication cabinet via fiber optic cable. Communication should be in accordance with 502-5.05.

e. Power. Should be in accordance with 502-5.04(01). Each cabinet location should be within 50 ft of either a main or remote service disconnect.

2. Truck Parking Information Sign. Truck parking information signs display the number of open truck parking spaces at upcoming rest areas, and consist of the following:

a. ITS cabinet. Should be in accordance with Section 502-5.03(04)

b. Panel sign. Should be in accordance with INDOT *Standard Drawings* and *IMUTCD* specifications with dynamic message punch-outs able to display 3 digits.

c. Communication. Should be in accordance with Section 502-5.05.

502-5.05 Plan Development Procedure [Del. Aug. 2022]

502-5.05(01) Site Reviews [Del. Aug. 2022]

502-5.05(02) Bucket Truck Survey [Del. Aug. 2022]

502-5.06 Supplemental References [New Aug. 2022]

This section provides additional documentation that may be considered throughout the project development process. This is list is not all-inclusive, and guidance in these documents does not supersede guidance provided in the Indiana Design Manual.

1. Federal Highway Administration *Research List of Online Reports and Technical Publications*
   https://www.fhwa.dot.gov/publications/lists/021.cfm
2. Federal Highway Administration *Ramp Management and Control Handbook*
   https://ops.fhwa.dot.gov/publications/ramp_mgmt_handbook/manual/manual/pdf/rm_handbook.pdf

3. Federal Highway Administration *Use of Freeway Shoulders for Travel – Guide for Planning, Evaluating, and Designing Shoulder Use as a Traffic Management Strategy*
https://ops.fhwa.dot.gov/publications/fhwahop15023/index.htm#toc
4. Federal Highway Administration *Road Weather Information System/Environmental Sensor Station Siting Guidelines*
https://ops.fhwa.dot.gov/publications/ess05/index.htm
5. Federal Highway Administration *Systems Engineering Guidebook for ITS*
https://www.fhwa.dot.gov/cadiv/segb/index.cfm
6. United States Department of Transportation *Systems Engineering for Intelligent Transportation Systems, FHWA-HOP-07 069, January 2007*
https://ops.fhwa.dot.gov/publications/seitsguide/index.htm
7. Minnesota Department of Transportation *Intelligent Transportation Systems (ITS) Design Manual*
https://www.mndot.org/its/docs/itsmanual.pdf
8. Federal Highway Administration *Tool for Operations Benefit-Cost Analysis (TOPS-BC)*
https://transportationops.org/tools/tool-operations-benefit-cost-analysis-tops-bc