OHIO DEPARTMENT OF TRANSPORTATION
OFFICE OF TRAFFIC ENGINEERING
RESEARCH IMPLEMENTATION PLAN

Title: Best ITS Management Practices & Technologies for Ohio

State Job Number: 14761
PID Number:
Research Agency: KHA of Ohio - Kimley-Horn & Associates
Researcher(s): Ann Massey, Edd Hauser
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Research Manager: Monique Evans
Sponsor(s): Dave Holstein, Tony Vogel
Written By: Omar Abu-Hajar
Study Start Date: 10/17/2000
Study Completion Date: 7/30/2001
Study Duration: 9 Months
Study Cost: $99,972.00
Study Funding Type: 80 Federal / 20 State, form ODOT SPR (2)

STATEMENT OF NEED:
In developing its intelligent transportation systems (ITS) program, the Ohio Department of Transportation sought to determine the best management practices and technologies being deployed by other departments of transportation across the country. The research focused on the experiences of the other states and the experts in the field. The effort is wide in scope, such as policy-level recommendations: what should the focus of ODOT's ITS program be? And, the study looked into micro-level technology questions, such as, what types of traffic detectors are most appropriate for Ohio.

RESEARCH OBJECTIVES:
The objective of this study was focused on answering three primary questions:

1) What are the causes of delay on Ohio's macro corridors?
2) What is the profile of an ITS program to best address the causes of delay on these routes?
3) What are the best practices and most cost-effective technologies to support Ohio's ITS program?

RESEARCH TASKS:
In order to understand and quantify the role of ITS technologies in overcoming the identified problems that currently exist in managing traffic and improving safety on Ohio's highways, three basic approaches were taken. The first approach was to evaluate problems and opportunities for improvement, as well as current deficiencies in ODOT's ability to deliver its services, in the three basic program areas of concern:

1) Recurring congestion.
2) Safety (specifically incident management).
3) Traveler information.

RESEARCH DELIVERABLES:
- The Final Report to document all research activities and recommendation.

RESEARCH RECOMMENDATIONS:

1. ODOT should consider installing and using non-intrusive detection methods wherever practical.
2. ODOT should continue its direction of procuring and installing 2070-Lite controllers and develop the capability to maintain these devices as well.
3. ODOT should make limited use of the large dynamic message signs typically mounted on sign bridges over multiple lanes of freeways, and that smaller, cantilever-mounted or median-mounted signs to be used in most situations.
4. ODOT should have a common ITS communications architecture/master plan defined for each region in the state to establish cost-effective deployment and operations of field devices and center components.
5. ODOT should have a collocation of police and fire agencies to be integral to ITS investments in urban areas of Ohio.
6. ODOT should centralize ITS operations and maintenance funding until ITS deployment becomes more widespread and integrated into District Offices.

PROJECT PANEL COMMENTS:

None

IMPLEMENTATION STEPS & TIME FRAME:

1. Apply the research findings to all ODOT ITS projects; this step has been implemented already.
2. Periodically review report recommendations for applicability to new projects; this step is ongoing.
3. Utilize the Technical Memorandum supplied by KHA of Ohio, Inc. dated April 19, 2001 for ITS projects when ODOT standards are not available; this step is ongoing. See Attachment A for this Memorandum.

EXPECTED BENEFITS:

- Technology recommendations that will become policy and be incorporated into the design of metropolitan and rural ITS systems.
- Opportunities for data sharing between different work units of the department

EXPECTED RISKS, OBSTACLES, & STRATEGIES TO OVERCOME THEM:

- Technology advancements, upgrades, and emerging federal standards; overcome by optimizing equipment replacements.

OTHER ODOT OFFICES AFFECTED BY THE CHANGE:

The results of this research impact many ODOT offices such as all of the Districts, Technical Services, Maintenance, Communications, IT, Construction, and Division of Planning. Attachment B shows a list of the (PAC) Project Advisory Committee members from different ODOT offices.

PROGRESS REPORTING & TIME FRAME:

There will be a quarterly report sent to the R&D Office showing all implementation activities with their respective completion in percent. An annual summary report will be provided by the program office for three years after implementation is complete to measure implementation costs and benefits for research performance purposes.

TECHNOLOGY TRANSFER METHODS TO BE USED:

- The final report was distributed to all other 49 state departments of transportation in addition to national libraries and repositories. It is also posted on the R&D web site.

IMPLEMENTATION COST & SOURCE OF FUNDING:
Implementation will be based on individual projects. If a project requires ITS, construction funds will pay for the needed items.

Approved By: (attached additional sheets if necessary)

Office Administrator:

Signature: Dave Holstein Office: OTE Date: 12/28/2006

Division Deputy Director:

Signature: Tony Vogel Division: DHO Date: 1/2/2007

Attachement A

KHA OF OHIO, INC.
An Affiliate of KIMLEY-HORN AND ASSOCIATES, INC.

Technical Memorandum

To: Howard Wood

From: Amy Massey

Date: May 24, 2001

Subject: Best ITS Management Practices and Technologies for Ohio
Task 5 Results

The purpose of this technical memorandum is to present the results of Task 5, as described in our letter dated April 19, 2001.

1. INTRODUCTION

A key element in achieving typical freeway management objectives is development of a conduit and pull box infrastructure that will facilitate a field communication network. The field communications plan requires a distribution system that would facilitate the installation of all required communication cables and power conductors.

This technical memorandum identifies options and discusses various considerations in selecting and designing a system to provide the conduit and pull box infrastructure for the ODOT ITS system. The focus of this technical memorandum is on the infrastructure needs specific to fiber optic cable. This background technical memorandum describes technical options, location requirements, and evaluates the costs associated with the different options.

2. GENERAL CONDUIT INSTALLATION AND PLACEMENT

Many freeway management systems employ two different conduit systems: one for communication cables and another for power conductors. A conduit system for communication cables should be able to handle both fiber optic cable and twisted pair cable. Other cables that potentially could share the communication conduit include control cables, loop detector cables, and other low voltage cables.

One of the goals of a robust communication infrastructure is to minimize tension on the cable during pulling. This in turn will maximize the length of cable that can be installed in a single pull, resulting in lower installation cost and greater spacing for pull boxes. Fewer pull boxes has the added benefit of fewer locations where the cable integrity is at higher risk due to rodents, ants, water infiltration, and other environmental actions. Communication cables are typically designed with a strength member that allows for pulls over greater distances than power conductors.

Power conductors typically require shorter conduit runs than communication cables. In addition, tighter pull box spacing is common practice. Also, many agencies prefer not to have communication cables and power cables in the same conduit system.

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When considering conduit placement, it is important to understand the system architecture and needs of the communication system. Most freeway management systems use a trunkline cable between a traffic center and hubs (also called nodes) located in the field. The field hubs are then linked together in either a linear or "ring" configuration to provide one or more communication paths between hubs and the traffic center. These rings allow communication to sections of freeway that are generally not located on or near the communication trunkline. Typically, the trunkline is accessed only at the hubs and traffic center.

A separate communication or distribution system is established from the hub, or in some cases, the traffic center, to the individual field elements, such as closed-circuit television (CCTV), dynamic message signs (DMS), and detector stations. If cable is utilized, there will be access points at each device.

Conduit that will be used for fiber optic cable should be installed as straight as practical to minimize the amount of pulling tension and maximize the length of cable installed with each pull. As a general rule, fiber optic conduit systems should not exceed 270° of cumulative bending between pull boxes. The total number of bends may reach 360° for short runs of 100 feet (30 meters) or less. Bending of the conduit should be accomplished by deflecting the run no greater than one foot for every ten feet (one meter for every 10 meters) in either the horizontal or vertical directions. At locations that will not permit a 10:1 deflection, factory bends may be used, with the flattest bend available (typical bends range from 11 1/4° to 90°). The number of 90° bends should be minimized. When used, fiber optic conduit bends should be gradual and of a large radius. Current ODOT fiber optic cable installation specifications (intended for providing a fiber optic communication link between intersections in an interconnected traffic signal system) call for the following minimum bend radii:

- 10 times cable diameter under no load (up to 180 lb or 82 kg)
- 20 times cable diameter under applied load (181-400 lb or 83-182 kg)

Main line fiber optic cable should enter and leave a pull box on opposite walls through factory-installed side knockout hole. If necessary, entry can be accomplished from beneath the pull box using 45°, large radius sweeps. The side entry method reduces the number of bends for the run, thus enabling longer pulls at lower friction. The 45° sweep approach provides greater flexibility in placement of conduit and pull box.

Different types of conduit systems should be evaluated in order to select what best suits the needs of the ODOT ITS system. The design options include the use of single conduits or multiduct conduit. Typical multiduct applications include the use of four one-inch (25-mm) diameter innerducts encased and protected by a four-inch (100-mm) Schedule 40 or 80 PVC outerduct, or the use of a number of 1-inch (25-mm) Schedule 40 PVC conduits locked together in formation (i.e. four conduits quad-locked in a square configuration). Quad-locked multiduct runs approximately $0.75 less per foot (300 mm) than multiduct with an outerduct.

Multiduct will allow for installation of future fiber optic cable(s) without removing or damaging existing cable. On the average, the installation of multiduct conduit with four ducts will cost on the order of $2.00 to $4.00 per foot (300 mm) more than standard three-inch (75-mm) conduit. Once trenching costs are considered, the order-of-magnitude cost of standard conduit verses multiduct is often insignificant. Depending on the type of conduit selected, various other issues should be addressed including inner conduit, duct plugs, expansion fittings, conduit terminations, and bends.

Installation of multiduct will give the communication system added spare capacity, depending on the number of cables installed. Typically, one cable is installed in one inner conduit. Most systems use one to three fiber optic cables. Accordingly, there are up to three spare inner conduits. The addition of a second multiduct greatly increases the capacity with only an incremental increase in cost.

Buried conduit is typically PVC or rigid metal. Most agencies are using PVC for fiber optic cable due to substantial cost savings and longer life; however, rigid metal provides greater protection and may be more appropriate in some installations. Conduit that will be exposed or placed in bridge structures should be either fiberglass or rigid metal.

3. COMMUNICATION CONDUIT INSTALLATION ALTERNATIVES

Alternatives for the deployment of fiber optic communications cable are included in the following categories:

1. Trenched or drilled
2. Direct-buried
3. Installed in median wall
4. Attached to bridges
5. Installed aerially

Each alternative is described below. Section 6 includes a comparison of rough order of magnitude (ROM) costs.

3.1 Trenched or Drilled Conduit

In locating the trench for conduit, many considerations should be evaluated prior to arriving at a recommended strategy. While an installation behind the shoulder is preferred, limiting factors in the field could make it necessary to install the conduit in the median area. Also, the conduit could be installed under pavements (typically in the shoulder area) by saw-cutting the pavements. The lateral distance between conduit and the edge of the roadway should be reviewed to determine the optimum path. This offset should consider existing and proposed utilities as well as ODOT facilities. Maintenance of the roadway as well as future system maintenance functions and potential freeway widening should also be considered. In some instances the terrain can dictate the trench location. Unless the median area is wide, traffic control is typically more extensive during installation and maintenance than it would be for conduit trenched along the shoulder.

An alternate method that is sometimes employed for areas with significant surface obstructions or crossings is directional drilling. Depending on soil conditions, directional drilling can install up to 600 feet (180 meters) of PVC conduit or rolled polyethylene conduit without disturbing the surface. The results are similar to that of jack and bore methods, except longer runs can be achieved at greater cost efficiency. Specialized equipment is needed to install conduit by directional drilling, so this alternative may not be practical.

Both the trunkline and the distribution cables should be installed in the same trench when possible to conserve construction cost. The most common shoulder conduit placement strategies are:

- *Main line trench on one side of freeway*
  This approach will yield consistency. Movement of people and vehicles during installation and maintenance activities relating to the main line trench can be accomplished in a sequential manner starting at one end and working to the other. An exception applies if an obstruction or physical constraint is identified rendering it unfeasible or cost-prohibitive to maintain trench on one side of the freeway. Thus, there may be select locations where the main line trench will move to the opposite side of the freeway for a relatively short distance in order to bypass an obstruction. Lateral conduit runs are necessary to cross the roadway to reach equipment on the opposite side of the roadway. Location of field devices can be weighted to the side with the main line conduit run to minimize the number of freeway crossings and associated costs for the communication system.

- *Main line trench on both sides of freeway*
  In the second approach, main line conduit is installed on both sides of the freeway between the traffic center and a hub, and between two hubs. While this approach typically yields a higher construction cost, the benefits include:

  - System redundancy by providing two communication paths between hubs.
  - Reduced need for distribution conduit crossings. (Distribution cabling is installed on both sides, and field devices will access the closest distribution cable.)
  - Greatest flexibility for system expansion.

The depth of conduit in trench should be held constant at 24 inches (600 mm). If a non-metallic conduit is used, a locator wire or detectable locator tape is needed to assist location efforts.

The trench configuration and backfill material should be investigated to determine what best meets the needs of ODOT. Some agencies have specified a slurry backfill to reduce settlement of the trench area and to provide additional protection against accidental damage from work performed after the conduit has been installed. Current ODOT fiber optic cable installation specifications (intended for providing a fiber optic communication link between intersections in an interconnected traffic signal system) require the placement of three-inch (76-mm) wide orange dielectric polyolefin film tape directly above all new conduit containing fiber optic cable as a warning. **Figure 1** is an example trunkline trench detail.

The National Electric Code (NEC) requires that conduit for communications be filled no more than 54% for a single cable.

Figures 2 and **3** are example details of conduit installation in fill sections. **Figures 4** and **5** are example details of loop detector/conduit and ramp metering controller/conduit installations along ramps in fill sections, respectively.

Figures 6 and **7** are example details of conduit installation in cut or flat sections. **Figures 8** and **9** are example details of loop detector/conduit and ramp metering controller/conduit installations along ramps in cut or flat sections, respectively.

Figure 10 is an example detail of conduit installation at overpass bridge structure (passing over crossroad).

3.2 Direct-Buried Conduit

Given the right soil conditions (loose, sandy, loam, etc.), it is possible to directly plow one-inch (25-mm) to two-inch (50-mm) polyethylene conduit (stored on reels) to an acceptable depth. Specialized equipment is needed to plow conduit, thus it may not be an option for small projects or local contractors. In addition, flat open space without crossing utilities or other conflicts is needed to accommodate the equipment and installation process.

3.3 Conduit Installed in Median Wall

For new construction projects, it is possible to install conduit within median walls and barriers that are formed in the field. Pull boxes can be built into the face of the barrier or wall or placed at grade. In either case, it is important to design the conduit in accordance with the radius and degree of bend criteria identified earlier in this document. ODOT Surveillance Junction Box Details include details on installing conduit, surveillance pull boxes, and lighting pull boxes in 50-inch (1270-mm) vertical top, battered top, and single slope barriers.

Although the use of conduit imbedded in a median wall can be advantageous in some situations, consideration must be given to the following complexities of this method:

- To conform to the size of the median wall, many barrier pull boxes have two dimensions that are 11 inches or shorter. If fiber is to be coiled or turned in the box, then the requirement for fiber optic cable minimum bending radius (10- or 20-times outside diameter) may be violated.
- Because of the size of median wall pull boxes, it is not feasible to install facilities for splicing fiber optic cable in the pull box.
- To access the trunk line cable, roadside devices will require a lateral conduit to be routed to the median. The installation of a lateral conduit typically requires directional drilling, which likely will dictate the closure of multiple travel lanes (to set up equipment) for an extended period of time.
- Careful planning of the placement of roadside devices is required to minimize the number of lateral crossings.

3.4 Conduit Attached to Bridges

Placement of the communications conduit across overpass structures should be evaluated to establish the most suitable location and means of supporting the conduit. When possible, the elevation of the conduit through the structure should be approximately the elevation of the conduit placement in the trench in order to avoid sharp directional changes. Long bridges may require equipment for various field devices and require special routing of conduit.

As shown in Figure 9, it is possible to install conduit down the embankment and beneath a crossing facility. However, conduit installations along a mainline over railroads and waterways typically require one of three methods:

- Installed within a cavity or cell of the bridge
- Attached to the underside of the bridge
- Attached to the parapet or side of the bridge

Figures 11, 12, and **13** are example details of conduit installations in/along overpass structures (I-beam and box girder). Aside from the installment method, other design decisions that will be necessary include:

- Steel versus fiberglass
- Aesthetics (if attached to the side or bottom)
- Expansion (need for one or more expansion couplings)
- Entry and exit points to and from the structure to minimize bending

It is fairly typical to place a pull box on both sides of a structure. If the degree of bending will exceed the 270° or 360° thresholds, then additional structure-mounted pull boxes (or junction boxes) will be needed.

3.5 Fiber Installed Aerially

Standards and guidelines for the aerial installation of fiber optic cable are articulated by ODOT (intended for providing a fiber optic communication link between intersections in an interconnected traffic signal system). Aerial installation is not commonly used for freeway communications systems.

4. PULL BOXES AND MANHOLES

Pull boxes are the primary access points for conduit and any cable housed in the conduit. The size and configuration of pull boxes should be determined based on the conduit configuration, type, size, quantity of conduit, splicing method, and required amount of spare cable.

A good design policy is to avoid installing pull boxes in the traveled way. Not only do these pull boxes require heavy-duty construction, but they also require traffic control to install and maintain. In all areas where there is a risk of heavy truck loading on the pull box and lid, they must be rated for AASHTO H20-44 loading. Typical reinforced concrete pull boxes are not rated for heavy truck loading, and at best may be able to sustain an infrequent loading when equipped with a steel lid.

If reinforced concrete pull boxes are used in areas that could potentially be subjected to infrequent vehicular loading, then a special concrete footing extending 6 inches (150 mm) around the outside of the box bottom should be considered to give added strength. Heavy-duty pull box lids should be considered even for areas not subjected to vehicular traffic to minimize maintenance activities and exposure of the communications system.

Composite pull boxes should be considered for fiber optic conduit runs. These boxes tend to cost more than reinforced concrete pull boxes, but offer a number of advantages including:

- More durable
- Less prone to cracked lids
- No metal reinforcing to rust
- Lighter weight (easier to store and install)

Composite pull boxes come in different load ratings. The concrete collar described above may not be necessary for composite boxes depending on the load rating of the box and the anticipated frequency of vehicle loading.

Pull boxes should not be located in drainage swales; pull boxes located on slopes should be placed horizontally and designed not to expose the side of the pull box that might be a hazard to traffic. Maximum pull box spacing criteria should be maintained for conduit installed on bridges. At each end of bridge structures, a pull box should be placed to facilitate the installation of cable and conductors. For communication cables, maximum pull box spacing of 1,000-1,500 feet (300-450 meters) is adequate for pulling purposes. Additional pull boxes should be installed sparingly, but in the vicinity of all field devices to provide communication access. Placement of pull boxes should also consider the conduit routing at the interchanges and potential splice points.

The minimum bending radius for fiber is approximately 13 times the outside cable diameter. (ODOT specifies 10-20 times cable diameter depending on applied loads.) The minimum pull box size should be determined in part by the minimum bending radius of the largest fiber optic cable, since excess cable is required in most pull boxes. To achieve consistency and provide flexibility for future growth, all pull boxes used for fiber optic runs should be sized to accommodate a splice closure as well as the minimum bend radius of the fiber cable. ODOT specifications call for a 24-inch (610-mm) X 35-inch (890-mm) X 26-inch (660-mm) pull box and indicates specific models and vendors.

In general, the use of a pull box will accommodate nearly all anticipated scenarios in routing conduit or cable for the ODOT ITS system; however, there are isolated cases that may warrant the use of a manhole or vault, including:

- Access required in non-freeway travel lane
- Frequent heavy vehicle loading
- Merge point for multiple branches and expansion
- Storage location for significant amount of slack cable

A manhole typically consists of a pre-cast concrete 4-foot (1.2-meter) diameter vault or ring(s) with base and cast iron frame ring and cover. Each manhole should conform to AASHTO HS20-44 standards. The manhole cover and frame should have a minimum diameter clear opening of 24 inches (600 mm) to 36 inches (900 mm). The cover should be secured to the manhole to discourage unauthorized entry or movement.

5. SPLICE CLOSURES

Fiber optic communication cables require an access point at each field device. At these locations, individual fibers of the fiber optic cable are either spliced or terminated in a manner that leaves the remaining fibers of the cable intact. Splicing and termination of the individual fibers can be housed either above or below ground.

Above ground splices are typically housed in a rack-mounted fiber distribution unit with a patch panel located in an equipment cabinet. Jumpers are utilized between the communication equipment and the patch panel. Fiber optic cable is either field terminated at the patch panel, or fusion spliced to a factory pigtail that is terminated at the patch panel. A comparison of the advantages and disadvantages associated with above ground splicing shows the following:

Advantages

- Easier access to fiber
- Less susceptible to moisture intrusion
- In smaller systems, all fibers in a cable can be terminated at the patch panel to provide greater flexibility (This approach would induce excessive signal loss in larger systems.)

Disadvantages

- More susceptible to dust and grime
- Communication cables are at-risk of vehicle knockdown
- Consumes cabinet space
- Increased handling of fiber optic cable

Below ground splices are housed using watertight underground splice closures. The fiber optic cable is fusion-spliced to a fiber optic pigtail (short run of fiber that is bare on one end for splicing, and terminated on the other) for patching or connection to communication equipment. A comparison of the advantages and disadvantages associated with below ground splicing shows the following:

Advantages

- Communication cables are not at-risk of vehicle knockdown
- Less complicated installation resulting in lower construction cost
- The fiber optic cable is not pulled into, and then out of each field cabinet
- Does not consume cabinet space
- Fusion splicing and the use of fewer terminations result in less signal loss/degradation

Disadvantages

- Poor construction methods can result in water/moisture infiltration
- Difficult to access fiber

Many freeway management systems utilize the underground splice approach at field cabinets and an aboveground approach at hub locations and traffic center. This combined approach offers flexibility for rerouting communication paths at the hub building while capitalizing on the benefits of an underground approach at field cabinets where flexibility is not generally needed, or could be provided on a case-by-case basis.

6. FIBER INSTALLATION COST COMPARISION

Table 1 includes a rough order of magnitude (ROM) comparison of costs associated with the various fiber installation alternatives discussed.

Table 1
ROM Costs per Linear Foot of Conduit

Method	**Trenched in Dirt**	**Drilled**	**Plowed in Dirt**	**Installed in Median Wall***	**Aerial**
In Conduit					
4-inch PVC Multiduct w/ Outerduct	$16.50	$22.50	N/A	$14.50	N/A
4-inch PVC Multiduct (4 1-inch conduits)	$15.75	$22.50	N/A	$13.75	N/A
4-inch PVC Conduit	$14.00	$20.00	N/A	$12.00	N/A
4 1-inch Polyethylene Conduits	N/A	N/A	$13.00	N/A	N/A
Overhead Using Existing Poles					
Lashed to stranded messenger	N/A	N/A	N/A	N/A	$3.00

* Does not include the additional cost of laterals that will be required for roadside devices.

The following assumptions were made in developing the ROM costs:

- Pull box, splice closure, cabinets, fiber optic cable, splices, and other costs that will not vary between installations will cancel out and thus are not included in the above values.
- Trench is assumed to have no slurry.
- Costs include delivery and installation given a large quantity and could be substantially higher for small jobs.
- It is assumed that the Contractor mark-up will be equal to the suppliers discount, thus list price is used.

The following unit-cost assumptions were made:

- Trench $12/ft
- Drill $18/ft
- Plow $11/ft
- Attach $20/ft
- In median wall $10/ft
- Conduit $1.00/ft
- Multiduct $2.00/ft
- Polyethylene $0.50/ft
- Conduit (delivered, list price) $1.00/ft
- Multiduct w/ Outerduct (delivered, list price) $2.50/ft
- Multiduct w/o Outerduct (delivered, list price) $1.75/ft
- Dielectric, Single Mode Fiber Optic Cable, $2.00/ft
- Stranded messenger, $1.00/ft

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Attachement B

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