WisDOT
Traffic Operations Infrastructure Plan
Communications System Layer

FINAL REPORT

Prepared for:

Bureau of Traffic Operations
Wisconsin Department of Transportation

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1.0 Executive Summary

1.1 Overview

In 2008, the Wisconsin Department of Transportation (WisDOT) completed the Traffic Operations Infrastructure Plan (TOIP), which outlined potential field deployments and their locations on a statewide basis. This plan included location, prioritization and cost estimation for the devices themselves, but did not include communications infrastructure to support the deployments.

To address this need, the Communications Systems Layer (CSL) considered connections to TOIP deployments, as well as a variety of WisDOT centers and partner agencies so that estimates could be created for an overall, statewide plan that provides specific technical recommendations and cost estimates for more than 1,400 individual points representing data users.

1.2 Problem Statement

The TOIP CSL addressed two primary issues:

1) Identify a viable communications method for each of the over 850 TOIP deployment sites and 600 additional roadside and center sites.
2) Create cost estimates on a per-connection basis, for deployment planning and to be used as a basis for negotiation with other infrastructure owners.

After reviewing the size and breadth of information involved in this project, it was quickly determined that it would require an approach that could handle large numbers of widely scattered data users, but still provide recommendations traceable to individual connections. The novel use of geo-spatial tools and data analysis enabled the rapid creation of draft estimates in a "bottom up" fashion, which considered each individual connection and the ability to respond to changing assumptions and connection targets.

1.3 Planning Approach

There are three main tasks in the approach to the planning process:

1) Develop geo-spatial database with deployment location, available fiber optic connection location, and deployment bandwidth requirements.
2) Develop rules-based structure for selecting communication methodology. Where possible, "typical" communication designs and cost estimates were applied.
3) Leverage Geographic Information Systems (GIS) to generate initial estimates and implement rules.

1.4 Tools and Techniques

Using GIS to conduct much of the analysis for this project lead us to use the ArcGIS (version 10) software. Its companion program, ArcGIS Network Analyst, was used to automate the analysis process with respect to fiber optics and associated cost estimates. In addition, in order to present the information in a more user friendly, open source format we used the Google Earth program. This allowed the information to be presented in a real world environment and provide the user a perspective that puts them in the field with the respective deployments. The ability to see data with high-quality aerial photography has been extremely powerful for users. Future uses of this tool, as well as web-based data visualization methods, are being explored to further use the CSL database to aid users in tracking and planning ITS deployments.

1.5 Estimation Results

Although each point has a communications method and cost associated with it, the large number of potential connections makes presentation difficult in a printed format. Therefore, the database itself has been supplied to WisDOT and the University of Wisconsin TOPS lab as a deliverable.

In addition, a wide variety of summarization is enabled by the use of geographic data. Table ES-1 below shows costs for TOIP elements summarized by the priority corridors created for the TOIP plan. Note that only the TOIP devices and any other elements (such as automatic traffic recorders) that fall directly along the TOIP corridor roadways are reflected in this summary.

Table ES-1 – Cost Breakdown by TOIP Corridor

TOIP Corridor	Cost Breakdown	Cost Using Preferred Communication Method
Badger State	**Corridor Total**	**$2,036,939**
	CCTV Sites	$1,384,850
	Non-CCTV Sites	$652,089
Capitol	**Corridor Total**	**$1,434,245**
	CCTV Sites	$589,345
	Non-CCTV Sites	$844,900
Fox Valley	**Corridor Total**	**$1,850,655**
	CCTV Sites	$1,389,577
	Non-CCTV Sites	$461,078
South Central Connection	**Corridor Total**	**$961,275**
	CCTV Sites	$728,540
	Non-CCTV Sites	$232,735
Hiawatha	**Corridor Total**	**$1,773,215**
	CCTV Sites	$934,727
	Non-CCTV Sites	$838,489
Wisconsin River	**Corridor Total**	**$616,946**
	CCTV Sites	$389,671
	Non-CCTV Sites	$227,275
Chippewa Valley	**Corridor Total**	**$581,647**
	CCTV Sites	$464,705
	Non-CCTV Sites	$116,942
Wild Goose	**Corridor Total**	**$775,891**
	CCTV Sites	$290,330
	Non-CCTV Sites	$485,560
Peace Memorial	**Corridor Total**	**$165,004**
	CCTV Sites	$100,080
	Non-CCTV Sites	$64,924
Cornish Heritage	**Corridor Total**	**$18,859**
	CCTV Sites	$8,807
	Non-CCTV Sites	$10,052
Titletown	**Corridor Total**	**$1,047,026**
	CCTV Sites	$595,104
	Non-CCTV Sites	$451,922
Southern Tier	**Corridor Total**	**$550,636**
	CCTV Sites	$481,662
	Non-CCTV Sites	$68,975
Glacial Plains	**Corridor Total**	**$484,398**
	CCTV Sites	$440,187
	Non-CCTV Sites	$44,211
Coulee Country	**Corridor Total**	**$356,311**
	CCTV Sites	$36,730
	Non-CCTV Sites	$319,581
Total ITS Element Cost for TOIP Corridors		**$12,653,047**

In addition, the project management team identified Priority Corridors to reflect the timeline envisioned for deployment. These corridors were identified independently of the TOIP corridors but can be related to them as needed, demonstrating the flexibility of the data-driven approach. Table ES-2 illustrates a time-based view of cost estimates with Figure ES-1 showing the envisioned limits of each priority corridor.

Table ES-2 – Costs by Priority Corridor

Costs Using Preferred Communication Method				
CSL Component	**Priority 1**	**Priority 2**	**Priority 3**	**Priority 4**
ITS Elements	$1,608,823.93	$2,149,942.59	$523,381.29	$1,605,600.08
CCTV Sites	*$792,245.71*	*$1,737,887.31*	*$310,832.60*	*$1,277,078.27*
Non-CCTV Sites	*$816,578.21*	*$412,055.28*	*$212,548.69*	*$328,521.80*
ATR	$83,988.04	$13,117.48	$34,182.43	$60,275.57
RWIS	$45,173.32	$15,207.02	$1,245.00	$15,231.12
Method 4 Cost / Priority	**$1,737,985.28**	**$2,178,267.09**	**$558,808.72**	**$1,681,106.76**

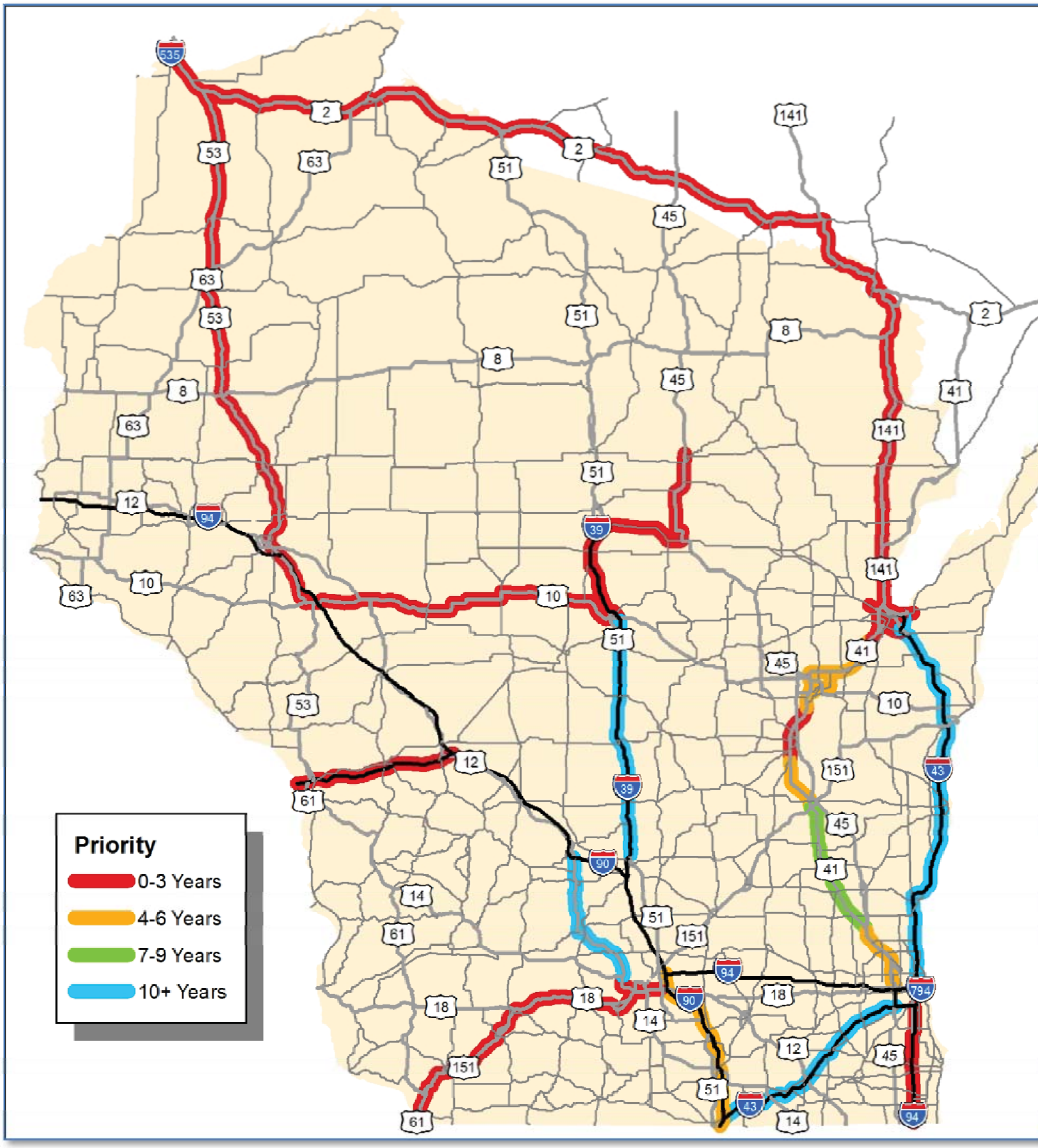


Figure ES-1 – Priority Corridors

2.0 Overview

2.1 Background

During 2007 to 2009, the Wisconsin Department of Transportation (WisDOT) undertook a large-scale planning effort to identify approximate locations and device types for ITS deployments throughout the State. The resulting Traffic Operations Infrastructure Plan (TOIP) defined deployments using 14 priority corridors and assigned "density" of device deployments based on a series of parameters, such as traffic volume and likely growth in the area.

Subsequently, a Deployment Plan was created to generate schedule and cost estimates for the installation planed in the TOIP. While these estimates included the equipment needed at each potential installation site, the needed communications infrastructure was excluded from this effort so costs could be kept as specific to each site.

Following completion of the Deployment Plan, the need to address the communications costs was recognized and an effort to create the TOIP Communications System Layer (CSL) was undertaken in 2010. While defining the scope of the CSL, WisDOT recognized the need to provide for communication service to a variety of entities beyond those identified in the TOIP.
As a result, a number of additional connections were considered for the CSL beyond the original TOIP planned deployments.

This document presents the data collection process, data analysis methods, schematic design and recommendations for the CSL.

2.2 Purpose

The CSL presents a basis for evaluating the relative costs of different communications alternatives for connecting various entities. While it does not identify a specific design solution for each, it does present concept-level alternatives and cost estimates for every connection. These can then be used to evaluate alternatives at design time and provide a value-basis for negotiation of leases for privately-provided services.

Because a geo-spatial database holds all of the location data, bandwidth needs, communications alternative and cost data, it is intended that the CSL be periodically updated as underlying assumptions are changed and more connections are built.

2.3 Products

The CSL products include several items:

- Final report
- Geo-spatial data in an electronic form
- Meta-data for the data describing field definitions and valid value

For the initial version of the CSL, the following entities were coded in the database as potential connection points:

- Automatic Traffic Recorders
- Department of Motor Vehicles service centers (DMVs)
- Highway Advisory Radio transmitters (HAR)
- Welcome Centers & Rest Areas
- Road Weather Information Systems (RWIS)
- Safety Weight Enforcements Facilities (SWEFs)
- University of Wisconsin Campuses
- TOIP Devices (CCTV, DMS, PCMS, other)
- Statewide Signals
- County Public Safety Answering Points (PSAPs)
- Level 1 Trauma Centers

Following completion of the CSL initial estimates and schematic design, the database will be transferred to a WisDOT partner for further analysis and maintenance.

3.0 Project Process

3.1 Approach

The CSL followed a step-wise approach that provided for consistent data management across a number of information types. Because of the large number of potential connections with differing needs and the likelihood of needing to revise assumptions during the analysis, a database to hold all data was created using ESRI'S ArcGIS software package.

To populate the database a series of steps progressively built upon the database to allow for a comprehensive plan. Each of the following items is described in detail in the subsequent sections:

- **Needs Assessment and Inventory** – Contact stakeholders in partner systems and document identities future needs and existing systems.
- **Assumptions** – Formalize underlying assumed priorities, preferences and limitations.
- **Spatial Data** – Create base data for all relevant fiber optic facilities and locate all potential points requiring data connections.
- **Typical Designs for Communications** – Define model connection methods for cost estimations.
- **Analysis and Assignment of Communications Methods** – Use the spatial database to assess costs and feasibilities of each of the typical design alternatives.
- **Output Checking and Corrections** – Verify that computer-generated solutions are viable and correct as necessary.
- **Database Creation and Summarization** – Aggregate data as needed and summarize for reporting purposes.

3.2 Needs Assessment and Inventory

Developed in 2008, the TOIP is a long-range planning document that outlines Wisconsin's statewide traffic operations infrastructure needs and opportunities. In addition to addressing infrastructure needs and opportunities, a series of technology recommendations and associated cost estimates were prepared at a concept level.

The TOIP documentation did not include the communications network enhancements needed to connect the ITS deployments. This was done intentionally to focus on deployment needs and not the complex interconnections of how the data is transferred. To fill this gap, WisDOT commissioned development of the CSL plan. As a part of this effort, the needs of various stakeholder entities were documented and assessed to determine the potential impact on future deployments. The purpose of this document is to summarize the needs assessment process and the information collected.

Interviews

To understand the existing communications infrastructure and anticipated needs, a series of interviews were conducted with project stakeholders who currently use or want to use Wisconsin's communication infrastructure. Interviews were conducted over a one-month period, with each interview generally limited to 60 minutes, except where the interviewee desired to extend the time. Interviews were typically conducted by a two-person team with one or two representatives from each stakeholder group.

Interviews followed a three-part format:

- Overview of WisDOT's TOIP and the desire to create the communications system layer for interconnecting the planned ITS elements.
- Discussion of the current communication methods employed by the interviewee and their organization.
- Discussion of anticipated changes or communication needs desired by the interviewee and their organization.

This format was adapted on a case-by case basis as needed, based on the interviewee's familiarity with the TOIP and their organization's existing communications infrastructure and anticipated needs.

In total, 15 telephone interviews were conducted with individuals covering 12 stakeholder groups. These interviews included personnel from various organizations such as WisDOT's Bureau of Highway Operations (BHO), the University of Wisconsin (UW) and Wisconsin State Patrol (WSP). Table 1 provides a list of interviewees and their respective organization.

Table 1 – List of Interviewees

Interviewee	Organization	Topic of Interview
Paul Keltner Don Schell	Wisconsin Department of Transportation – Bureau of Highway Operations (BHO)	Wisconsin Emergency Management (WEM)/Emergency Operations Center (EOC)
Mike Adams	WisDOT - BHO	Road Weather Information System (RWIS)
Jeff Ohnstad Geoffrey Snyder	Wisconsin Department of Transportation – Wisconsin State Patrol (WSP)	Wisconsin State Patrol (WSP)
Robert Spoerl	WisDOT - BHO	Rest Areas
John Williamson	Wisconsin Department of Transportation – Transportation Investment Management (DTIM)	Traffic Data Recording Systems
Sharon Bremser	WisDOT - BHO	Automatic Vehicle Location (AVL) and maintenance fleet communications
Jon Morrison Debi Odekirk	WisDOT - WSP	Public Safety Answering Points (PSAPs)
Steven Parker Peter Rafferty	University of Wisconsin – Traffic Operations and Safety (TOPS) Laboratory	University of Wisconsin Traffic Operations and Safety (TOPS) Laboratory
Joanna Bush	WisDOT - BHO	Signals
Mike Schlicht	University of Wisconsin – Office of Learning and Information Technology	University of Wisconsin inter-campus communications
Peter Lynch	UW –TOPS	Weigh-in-Motion (WIM)
Don Schell	WisDOT - BHO	Interstate Connections & Fiber Access Points

Feedback from stakeholders covered a wide range of topics. Several themes emerged from discussions that can provide the basis for summarizing Wisconsin's existing communications system and projected needs.

Existing Communications Infrastructure

Based on discussions with project stakeholders from various organizations, information regarding WisDOT's existing communications system was obtained. From these interviews, follow-up correspondence took place as necessary to gather additional information including schematics and maps of communications infrastructure. This infrastructure can be broken down into different communications media and are described accordingly.

Fiber Optic Communications

The primary communications medium throughout the State of Wisconsin is fiber optic communications. WisDOT has obtained fiber optic communications along the State's major corridors through fiber leases and agreements, exchanging right-of-way fees for fiber and by installing their own fiber optic cable where needed. Additional fiber optic communications have been deployed to the Department of Military Affairs and Wisconsin State Patrol to provide critical communications to local offices.

Wisconsin's fiber optic communications system (ITSNET) is based on backbone fibers connecting the major cities of Hudson, Eau Claire, Wausau, Green Bay, Milwaukee, Madison and Tomah. Some of this fiber is leased by WisDOT from other communications agencies. For communications from Eau Claire to Milwaukee (via Green Bay), WisDOT leases fiber from Qwest for communications. For communications to continue from Milwaukee to Madison and back to Eau Claire (via Tomah) and eventually Hudson, WisDOT has an agreement with AT&T (formerly Touch America) where right-of-way fees were exchanged for fiber. Additionally, fiber is leased from PAETEC to provide communications via fiber between Green Bay and Madison via USH 41 and 151.

This fiber optic network utilizes SONET technology to provide a high capacity and reliable network for communications purposes. To provide redundancy, ring topology is used wherever possible. To maintain and provide access to the SONET network, ITSNET includes 17 SONET devices located at various points-of-presence (POPs) which are primarily located at WisDOT facilities. For future expansions, WisDOT is deploying 100 Mb/sec and 1 Gb/sec Ethernet networks and connecting to existing fiber optic backbone at established POPs.

Along the fiber backbone, there are access points for various devices and agencies. This includes connections to ITS components, such as closed-circuit television (CCTV) cameras and dynamic message signs (DMS). Connections also exist at other facilities such as Wisconsin State Patrol (WSP) and Department of Military Affairs (DMA) offices. In order to provide communications to other states, ITSNET includes fiber communications to the Minnesota DOT's Regional Traffic Management Center (RTMC) from Hudson, Wisconsin, to Roseville, Minnesota, and to the Illinois Tollway via Kenosha to Toll Plaza 21 on I-94 in Illinois.

More extensive fiber networks exist in major cities, primarily Madison and Milwaukee. In Madison, the University of Wisconsin has installed fiber optic cables throughout campus. There is also a fiber connection to the University of Wisconsin Traffic Operations and Safety (TOPS) Laboratory where a large amount of DOT data is managed. There is a fiber connection between WisDOT's offices at Hill Farms to ITSNET. The City of Madison maintains fiber within the City as emergency responders, such as local police and fire departments, who use the fiber for critical communications. In addition to these fibers, WisDOT also maintains communications to DMS and CCTV within and near the City of Madison.

The City of Milwaukee has connections to similar agencies. This includes connections to City offices, DOT-owned deployments, and larger transportation facilities, such as Amtrak stations and General Mitchell International Airport.

Wireless Communications

Wisconsin State Patrol

The largest wireless network in the State of Wisconsin is managed by the Wisconsin State Patrol (WSP). This network is based on IP MobileNet technology, provides coverage to 99 percent of the State, and allows for communications between WSP personnel and facilities as well as the Wisconsin Department of Natural Resources (DNR).

Two OC3 microwave rings, which are owned and maintained by WisDOT, provide the communications backbone for this network. The first ring starting in DeForest, continuing to Spooner, Wausau, and back to DeForest, consists of communications between towers operating at 6 GHz OC3 and 6 GHz DS3 speeds. The other ring, operating at 6 GHz DS3 speeds begins in DeForest and continues to Waukesha, Green Bay, and Wausau before returning to DeForest. From these rings, data continues to remote towers via 6 GHz DS1, 5.8 GHz, 2.4 GHz and 960 MHz FT1 communications, yielding a total of 101 towers. These towers relay communications with WSP and DNR vehicles with communications operating on a 150 MHz very high frequency (VHF) network. This network is able to provide data communications at a rate of 19.2 Kb/sec. To provide greater bandwidths, WSP vehicles are also equipped with NetMotion routers to allow seamless roaming between network where Wi-Fi or cellular communications are present.

Wireless Broadband

To communicate with closed-circuit television (CCTV) cameras along the Madison "Beltline" (USH 12/18), WisDOT uses wireless communications consisting of ENCOM radios operating at 5.8 GHz and 900 MHz. This wireless network begins at the intersection of USH 12/18 and John Noel Drive and continues west approximately six miles connecting six CCTV cameras to a network access point at John Nolen Drive. At John Nolen Drive, a RuggedCom RS900 provides communications from the six CCTV cameras to 100 Gb/sec Ethernet returning to the WisDOT office located near the Dane County Regional Airport.

A wireless communications network has also been established in Rock County along IH 39/90. This wireless network is based on radios installed on CCTV poles and connected to existing splice vaults along IH 39/90 at State Line Road and USH 14. These radios communicate with five CCTV cameras and five microwave detectors with ENCOM CommPak BB radios using point-to-point and point-to-multipoint topologies.

WisDOT also uses wireless communications in Merrimac, Wisconsin, to enable ferries crossing Lake Wisconsin to display messages on dynamic message signs that are at both sides of the lake crossing. This system uses 802.11 wireless Ethernet bridges located in cabinets at both sides of the crossing to communicate with a ruggedized tablet PC installed on board the ferry. From this PC, ferry operators can provide messages as necessary to personnel at either side of the lake crossing.

Other Communications Medium

Beyond fiber optic and wireless communications, a number of other communication mediums are used by WisDOT and its various entities. These communications media are not nearly as prevalent within the State, but are important to note when assessing WisDOT existing communications infrastructure.

Landline Communications

Landline communications are also used by WisDOT for connections to all Road Weather Information System (RWIS) and some Automatic Traffic Recorder (ATR) sites. Landline communications are primarily used where fiber is not easily accessible but telephone communications are available nearby.

Cellular Communications

To provide communications to remote locations or to mobile equipment, cellular communications are used. This includes communications to remote ATRs and Weigh-in-Motion (WIM) sites. Additionally, cellular communications are used as a communications alternative to achieve greater bandwidth for state patrol vehicles equipped with a NetMotion router.

Needs Assessment

A number of needs were common among multiple interviews and project stakeholders. These ideas can be grouped into two main themes and are described in detail based on the functional item desired and the specific communications mechanism required to meet the stakeholders' needs. The primary sources for the data are referenced in parentheses.

Common Themes

Theme 1: High-Speed Wireless Network

A number of interviewees expressed the need for a high bandwidth wireless network along Wisconsin's major corridors and highways, each within their own context.

Wisconsin State Patrol (WSP)

WSP would like their vehicles to be able to transmit larger amounts of data at faster speeds over a wireless network. The current WSP network, based on IP MobileNet products, operates in the 150 MHz very high frequency (VHF) band and can achieve speeds of 19.2 kilobits per second. A NetMotion router in the patrol vehicle allows for higher data rates, but this is only available where cellular or WiFi hotspot coverage is present. Due to the slow speed of the network, users are not able to use features such as video streaming or applications that require large amounts of data transfer (high-resolution photographs, etc.). They would like enough bandwidth to share bi-directional, compressed video streams and other multi-media data types to and from vehicles. An upgrade to the IP MobileNet network planned for 2012 will raise both the available data transmission rates and the number of simultaneous users possible on the network; however, this will not address the long-range need for multi-media applications.

WisDOT Test Bed

Expressing a similar need for high-performance wireless communications, a number of WisDOT personnel have proposed deploying a wireless network test bed along a major corridor. This would enable vehicles and fixed devices to have continuous communications at speeds that allow them to support demanding applications such as video surveillance, traffic management and mobile applications without extensive fiber optic infrastructure.

WisDOT (County) Maintenance Fleets

Maintenance personnel also expressed a need to achieve more reliable mobile communications. Currently, maintenance vehicles (in particular snow plows) use cellular communications to share data while performing maintenance operations (i.e., plowed locations and pavement temperatures). This system is not entirely satisfactory; cellular networks do not have adequate coverage on rural Wisconsin roadways. Maintenance vehicles are able to upload and download road condition data at maintenance facilities; however, it may be up to 10 hours between downloads, which makes the data too old to be useful in real-time.

To achieve more reliable communications for maintenance vehicles, there is a desire to create "hot spots" along plow routes where vehicles can download road condition data to maintenance facilities. This would enable snow plows to communicate data in areas lacking adequate cellular networks without having to take the additional time to travel to a maintenance facility.

These different stakeholders expressed different requirements and uses for high-speed wireless data systems, but the overall need for such a system is clearly expressed.

Theme 2: Redundant and Center-to-Center Communication Facilities

Due to the critical nature of some data shared over communications infrastructure, several interviewees expressed interest in robust, redundant communications facilities that would be resistant to failures. The exact requirements varied among organizations as different stakeholders had unique concerns.

University of Wisconsin Inter-Campus Communications

The University of Wisconsin maintains an extensive, high-capacity data communication system to serve educational needs. Like WisDOT, the University uses a combination of owned and leased fiber optic facilities for data transport. With the long distances and large volumes of data moving between campuses, the University desires a minimum of two independent fiber routes entering all two-year and four-year campuses. By having two or more independent routes, network downtime is minimized as it unlikely that two fibers in separate locations would be inoperable at the same time. This would also allow the network to be fully functional during any planned maintenance operations.

University of Wisconsin TOPS lab

The TOPS lab currently has a 50Mbit/sec fiber optic link with the WisDOT network and State Traffic Operations Center (STOC). The types of data exchanged on this link have gradually expanded and now include increasingly critical functions, such as providing WSP computer aided dispatch (CAD) incident data to the STOC and distributing surveillance video from the STOC to various users. This is anticipated to increase as TOPS begins receiving crash reports and photographs monthly from WSP.

Since some of the data exchanged is used to enable real-time traveler information services such as 511wi.gov, a redundant data transport is desirable.

Public Safety Answering Points (PSAPs)

The systems used by PSAPs are somewhat self-contained to prevent external events from degrading dispatch/call handling capabilities. However, there is a trend toward increasing the ability of other centers to view the calls handled by one another and potentially provide "back-up" call answering and dispatch capability. This trend will be accelerated by the adoption of "Next Generation" or NG911 systems that will be deployed over the next five to 10 years throughout the State. Dane County is believed to be in the first stages of deploying this type of redundancy with other PSAPs.

There is also a desire to have direct access to sensor and surveillance data on WisDOT roadways as they enter a PSAP's dispatch area. This would permit a more informed dispatch operation through the use of RWIS, vehicle detection and direct video monitoring of major traffic routes.

Given the critical nature of the services provided, interviewees representing the PSAPs indicated that they would like to have redundant communications to their call centers. Although very small amounts of critical data is currently moved over wide area networks, change is anticipated in the mid- to long-term. Redundant network communications would ensure that communications would still be present if their primary network became unavailable.

To meet these various requests, all interviewees expressed interest in communications taking place over a fiber network. This is primarily due to the large bandwidth and high reliability of fiber optic cable. To prevent the fiber optic cable from being damaged at the same time as other communications cables, a desire to install the fiber along a separate route from other communications was expressed.

Unique Themes

A variety of communications needs were expressed during interviews, many of which were specific to the interviewee. Despite the fact that these needs were not common among project stakeholders, several significant communications system enhancements were suggested.

Signal Interconnect and Central Monitoring

WisDOT would like to establish improved coordination and monitoring of signal systems. Currently, signals are managed at a local level with minimal coordination and regional monitoring. By interconnecting signals and developing a central management system, WisDOT could provide regional traffic management by managing traffic flow on a regional level rather than a street by street basis. Local areas would also benefit by having access to specialized traffic engineering expertise available at WisDOT. Additionally, with a central management system, WisDOT could manage emergency traffic situations, such as a city-wide evacuation during dangerous weather conditions.

Weight Monitoring at Critical Infrastructure

Interviewees that work with Weigh-in-Motion (WIM) systems requested that communications be established to allow for more WIM sites to be installed at critical infrastructure. This would include bridges and other roadways in areas with extreme freeze-thaw cycles or poor soil conditions exist. By installing WIM sites at these locations, valuable information can be obtained to guide maintenance work to prevent additional repairs to critical infrastructure.

Interstate Connections

WisDOT has expressed interest in establishing additional interstate connections to allow for communications between state agencies. Currently, communications exist with Illinois and Minnesota along I-94. However, WisDOT would also like to establish communications with Iowa between Platteville and Dubuque. Additionally, WisDOT is interested in establishing redundant communications with Minnesota and Illinois via Rochester/La Crosse and Rockford/Beloit, respectively.

These connections would allow WisDOT and neighboring states to share information such as camera feeds and traffic flow data. This would allow for better traffic management and incident response across state borders.

Automatic Traffic Data Recorders

WisDOT also expressed interest in obtaining redundant communications for Automatic Traffic Recorder (ATR) sites. Currently, ATR sites are connected via cellular modems or landlines. Landlines have proved unreliable as they can be cut or damaged causing a loss in communications. As a result, WisDOT will continue to use cellular modems at future ATR sites; however, fiber optic connections would be desirable if cost effective. This would allow faster and more frequent communications and create redundancy within the current communications networks.

Road Weather Information Systems (RWIS)

The State's network of RWIS sensor sites is currently connected via dial-up/landline connections to one of three data collection servers located at WisDOT offices. Data is then transferred from these servers to a data processing facility operated by Vaisala, Inc. via FTP on an Internet connection.

The system of telephone company-provided links has proven to be cumbersome from a management standpoint and incurs significant recurring costs. As a result, a Request for Proposals (RFP) is in development that would contract with a third party to provide an "always on" network connection, most likely using cellular data communications.

However, as part of the US Highway 41 design near Green Bay, fiber optic connections are planned for the sites in the area. This is a preferred mode of communication due to its high capacity, reliability, and low recurring cost. If fiber communications were cost-effective to install, it would partially replace the scope of the RFP in development now.

Summary

In summary, the needs assessment information provided here serves as a recap of information gathered as part of the stakeholder outreach effort. This information will be used to guide the development process in order to cost effectively meet the needs of the users and the budgetary concerns of WisDOT. The interview minutes are presented in the Appendix.

3.3 Assumptions

Introduction

To allow a data-driven planning effort, a set of enabling assumptions was required to enable rules-based selection of communication alternatives and projections of potential fiber builds. These assumptions simplified communications planning by limiting the ways in which communication service could be supplied and setting fixed limits on cost for each.

General Assumptions

WisDOT Owned Fiber Facilities

Where feasible (based on the assumptions described in the following sections), a connection to fiber optic facilities owned by WisDOT was the preferred method of connection. On these facilities, it was assumed that a connection could be made at any existing splice vault.

In practice, it may be feasible to add an additional vault closer to an ITS device or relocate the device to minimize the connection cost. For planning purposes, only existing vaults were used on the I-94 corridor. After consultation with the Project Management Team, it was determined that vaults could be added as needed in some urban areas (such as some areas in Milwaukee, Madison, Eau Claire, and Green Bay). These were coded with a special numeric identifier (800-899) in the database and an assumed connection distance of 50 meters to the point to be serviced.

Several major fiber optic facilities are expected to be completed by 2012 along WisDOT right-of-way. Since these have yet to be designed, no information was available for the locations of points at which devices could connect. Since WisDOT is able to negotiate for placement of splice points, it was assumed that these could be placed within 50 meters of a device location. These were coded in the database as "999" to indicate a planned splice point.

Leased Fiber Facilities

WisDOT has made extensive use of leasing agreements to provide access to fiber facilities it does not directly own. While these provide cost-effective long-haul services, they do not provide the convenience of connection at every splice vault and adding additional splice vaults can be highly problematic.

For the CSL, the practice of building a fiber optic extension from an existing communications hut to roadside devices as currently done by WisDOT was used.

Wireless Systems

Various types of wireless data systems have been used by WisDOT for a wide variety of applications. For the CSL, three types of wireless connections were assumed to be available:

- **Wireless Broadband (802.11g, WiMax or similar technologies).** Since these links are able to carry multiple channels of digital video, they are suitable for use with CCTV-equipped sites. Because the performance of broadband devices are highly dependent on local line-of-sight and noise characteristics, as maximum range of two miles was assumed. In practice, this distance may be substantially longer or shorter at each site.

- **Cellular Modems.** Cellular coverage along Interstate highways and in urban areas is generally good, and cellular service provides a cost-effective option for low data-rate uses, such as message signs or weather monitoring stations. In less populated areas of northern Wisconsin (north of Eau Claire and Green Bay), cellular coverage is much less complete. For this reason, cellular communications are not planned to be used north of STH 29. During design, a site survey may indicate adequate coverage at specific deployment points, and the communication method can be adjusted at that time.

- **Data Radios.** The Wisconsin State Patrol and Department of Natural Resources maintain an extensive wireless communications network for both data and voice services. WisDOT has used this system to support devices in the past, and upgrades to the network in the 2010-2011 timeframe make this an attractive option where cellular communications are not feasible. Give the 99% coverage available in Wisconsin, a data radio was assumed to be a viable low-bandwidth option in place of the lower-cost cellular modem.

Initial Specific Assumptions

Several specific assumptions formed the basis of the communication method selection rules. These were intended to provide distinct cut-off points for method selection, although during design it is expected that some flexibility and engineering judgment will be required to make a final selection. The assumptions used for the first set of assignments are listed below:

1. Fiber optic was the preferred method of communication.

2. The maximum standard cost for a fiber connection was $40,000.

3. All TOIP sites connected via fiber (if possible for less than $40,000) and all sites within two miles connected via wireless broadband.

4. TOIP sites with fiber cost greater than $40,000 need further analysis.
5. TOIP sites with fiber cost greater than $100,000 removed from analysis (need to determine alternative communications method).
6. CCTVs require 4 Mb/sec via fiber or wireless broadband.
7. DMVs, SWEFs, UW, Welcome Centers and Rest Areas require 10 Mb/sec via fiber connections.
8. ATRs, HARs and RWIS require 9,600 b/sec and given maximum fiber cost of $20,000.
9. ATRs, HARs and RWIS that cannot connect to fiber for less than $20,000 are given cellular modem.

Revised Specific Assumptions

After an initial pass of the planning process had selected a communication method for each of the points, the results were reviewed with the Project Management Team on a point-by-point basis. Several modifications were then developed to more accurately reflect WisDOT's priorities and reasonable maximum values:

1. Fiber optic was the preferred method of communication.
2. The maximum standard cost for a fiber connection was $50,000.
3. All TOIP sites connected via fiber (if possible for less than $50,000) and all sites within two miles connected via wireless broadband.
4. TOIP sites with fiber cost greater than $50,000 need further analysis.
5. TOIP sites with fiber cost greater than $100,000 removed from analysis (need to determine alternative communications method).
6. CCTVs require 2 Mb/sec via fiber or wireless broadband
7. DMVs, SWEFs, UW, Welcome Centers and Rest Areas require 10 Mb/sec via fiber connections.
8. ATRs, HARs and RWIS require 9,600 b/sec and given maximum fiber cost of $10,000.
9. ATRs, HARs and RWIS that cannot connect to fiber for less than $10,000 are given cellular modem.

3.4 Spatial Data

To enable analysis of a large number of potential connections, a complete geo-spatial database was required for data management purposes. Construction of the database involved defining all of the potential "users" of data as well as all of the possible points at which connections could be made.

Given the assumption that fiber optic was the preferred medium for data transport, a complete database of not only WisDOT fiber facilities (cable locations as well as splice vault points) was created, but also the cable locations, splice locations and communications "hut" locations for facilities where WisDOT leases fiber optic capacity from private providers. Creation of this data required the manual entry of data from paper 100-scale plan sheets, as electronic versions were not available. In all, approximately 2,740 sheets were reviewed and relevant information entered into the database for later use.

Each of the points at which a connection was to be made (ITS device, PSAP, DMV center, etc.) was assigned latitude-longitude coordinates and a bandwidth requirement based on the type of device/user requirement. By treating each connection as a geographic point with a numeric bandwidth need, connection planning could be treated as a geographic network routing exercise by GIS software, rather than planning for each point individually.

The spatial database was reviewed with the Project Management Team in September 2010 and subsequently revised based on their input for future planning estimates.

The steps below outline the process used to generate the paths for potential fiber optic connections using network analysis software:

1. Locations were divided into two groups: "incidents" – devices that needed data service and "facilities" – points at which a network connection was available.
2. A network of all State jurisdiction roads was used to provide available paths from incidents to facilities – this allowed fiber to be routed on only State right-of-way.
3. ArcGIS computed paths from each incident to nearest facility.
4. Due to limitations in the "smartness" of the routing algorithm, paths were then hand-checked and corrected.
5. After final paths were complete, costs were computed and method selection rules applied.

3.5 Typical Designs for Communications

To effectively plan for a large number of potential communications deployments, an approach using a limited number of communications models accompanied with a "typical" design and set of cost assumptions. While each site, whether a roadside device or office structure, a range of data communications options are available as a model selection.

When developing the options, the existing WisDOT ITS procurement list was referenced as much as possible to ensure realistic costs and maximize compatibility with existing systems and spare parts inventory. Models have also been simplified so that they are applicable to the widest range of potential connection sites. In all cases, it is assumed that an existing (or planned) electronic interface will be the point of demarcation between the CSL connection and the remote facility. In other words, the remote facility will have a serial or Ethernet connection for its data with an existing electrical or fiber optic interface.

Five models were developed for planning purposes. These included Ethernet (100 or 1,000 Mb/sec connections) over fiber optic media, Unlicensed wireless broadband connections to a "backhaul" link, Cellular modems with EVDO/UTMS high data rate connections, licensed data radios operating on the Wisconsin State Patrol (WSP) network and leased services (such as dial-up and T-1 circuits) from telecommunications companies.

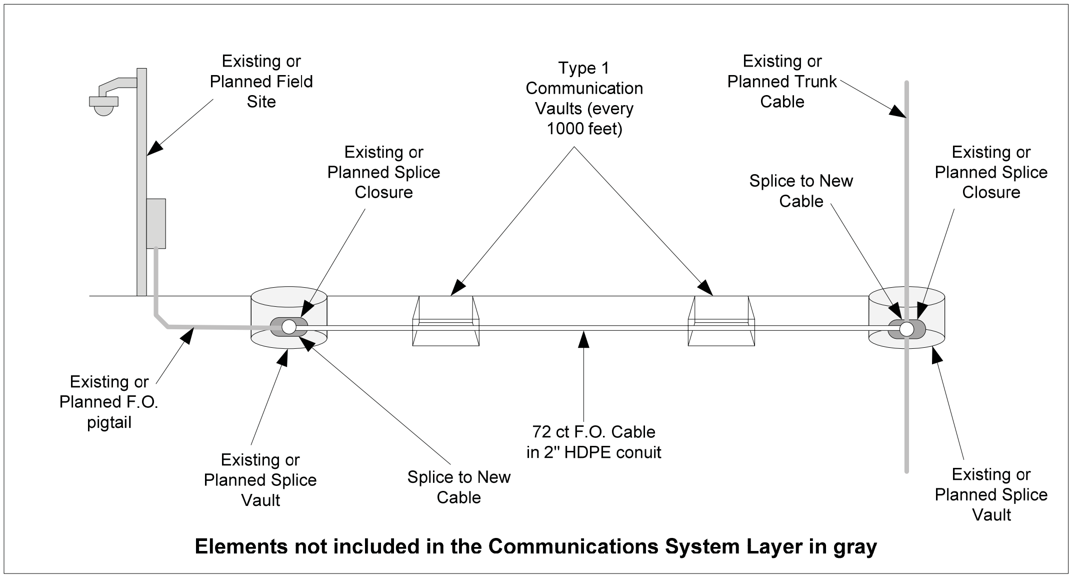
Typical Schematics and Cost Assumptions

A short description of each of the communications models is presented below. Selection of a given model for a particular site was governed by the GIS-based system developed for the project and a site-by-site review of the connections generated.

Fiber Optic

The fiber optic model encompasses the physical items needed to create the connection between a remote site and some portion of the ITS NET SONET system used for high-capacity, high-reliability data communications. The electronics to connect to the new fiber infrastructure are assumed to be in place at each end of the link.

Figure 1 – Typical Fiber Optic Schematic



The table below shows assumptions based on current design work being conducted for WisDOT. Items that are needed periodically along runs of fiber are included as an average cost per foot, although the exact numbers of items such as vaults will be dependent on the precise design of the cable installation.

Table 2 - Typical Fiber Optic Cost Assumptions

ITEM	Unit	Unit price	Assumptions
Install Fiber Optic Cable Outdoor Plant 72-CT	Average per foot	$2.25	
Cable, Fiber Optic, 72 Count, Dielectric, Furnish Only	Average per foot	$0.47	
Conduit HDPE 3-Duct 2-Inch	Average per foot	$6.00	
Communication Vault Type 1	Average per foot	$1.60	1 CV every 1,000 feet ($1,600 each)
Fiber Optic Splice	Average per foot	$0.36	Splice every 10,000 feet (72 splices @ $50 each)
Fiber Optic Splice Enclosure	Average per foot	$0.06	1 SE every 10,000 feet ($630 each)
	Average Total Cost per Lineal Foot	**$10.74**	

Wireless Broadband (PTP)

The use of wireless networking technologies has increased in popularity over the last five years, as a wider range of products with more attractive price/performance ratios has become available. WisDOT has implemented a variety of these products using different topologies to facilitate cost-effective data communications to a number of roadside devices, including CCTV cameras.

For planning purposes, a Point-to-Point (PTP) topology was assumed with a “remote” device connecting to a “master” device that in turn is connected to a fiber-optic backhaul link or other-high bandwidth, high-reliability connection. The hardware considered has been previously deployed by WisDOT and has shown good performance when installed and configured properly.

Figure 2 – Typical Wireless Broadband Schematic

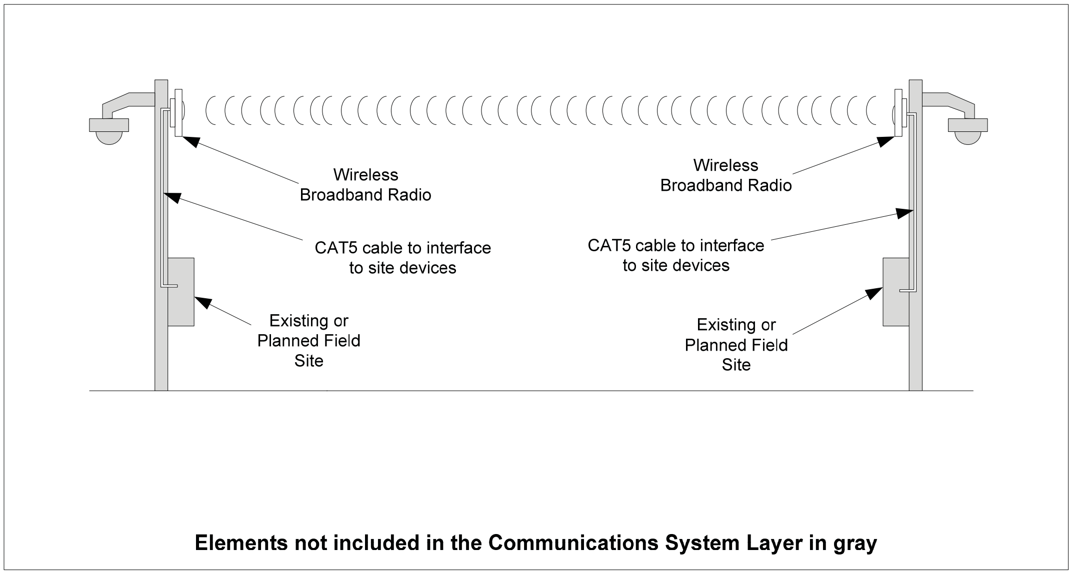


Table 3 - Typical Wireless Broadband Cost Assumptions

ITEM	Unit	Quantity	Unit Price	Total Cost	Assumptions
Radio (two needed)	each	2	$1,694.00	$3,388.00	Encom BB58
Cable (Cat5)	ft	200	$0.30	$60.00	Includes Installation
Installation	each	2	$1,000.00	$2,000.00	10 person hours per node
			Total Install Cost	**$5,448.00**	

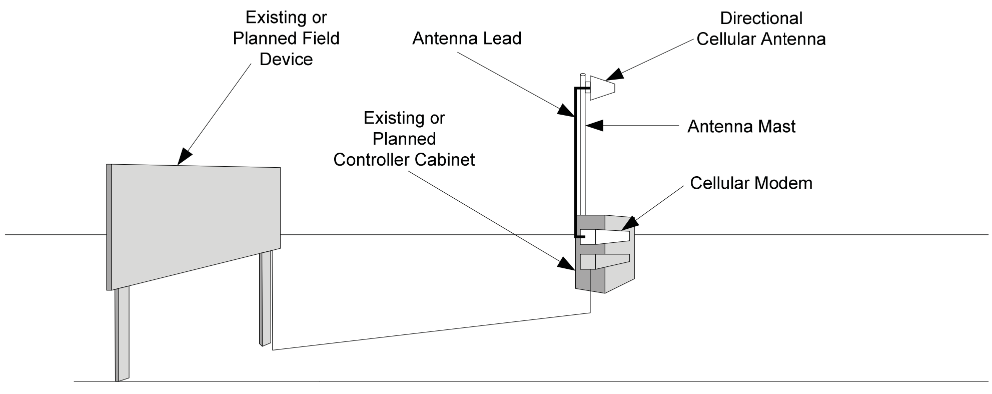
Cellular Modem

Data communications using cellular data networks has improved greatly over the last decade. This method may be considered for most applications and even video transmission, provided that the usage is an on-demand basis rather than a continuous (24/7) use model. Current EVDO networks can support speeds up to 2.4 Mb/Sec and newer HSPA systems can operate at 14-21 Mb/sec.

Although capable of very high performance, installation concerns such as signal strength, noise floor and number of devices connected to a single tower may drastically reduce actual throughput. In addition, it is known from experience that some areas in northern Wisconsin lack sufficient coverage for this model to be effective.

The typical installation includes a cellular modem that is ruggedized for vibration and temperature extremes and a directional antenna, which can substantially improve performance in remote locations. Unlike fiber optic communications or wireless broadband options, cellular communications will incur a monthly recurring cost in addition to any hardware maintenance.

Figure 3 – Typical Cellular Modem Schematic



Elements not included in the Communications System Layer in gray

Table 4 - Typical Cellular Modem Cost Assumptions

ITEM	Unit	Quantity	Unit Price	Total Cost	Assumptions
Modem	each	1	$659.00	$659.00	BT-6800
Directional Antenna	each	1	$70.00	$70.00	Wilson 301135
Antenna Lead	ft	50	$0.50	$25.00	
Installation	each	0.5	$1,000.00	$500.00	
Recurring Cost	month	1	$30.00	$30.00	
			Total Install Cost	**$1,254.00**	

WSP Data Radio

In addition to cellular communications and wireless broadband, the WSP radio system offers a method to move low-bandwidth data over large distances. The primary advantage of the system is its wide coverage, with 99% of Wisconsin being served. This approach does have significant limitations, however. The current maximum data rate is 19.2 Kbits/sec, satisfactory for detection and sign control applications, but not for streaming video. More significant is a system limitation of 16 simultaneous "slots" being available on a given base station radio at a given time. This can create a situation in which emergency uses can be "locked out" by having several ITS devices using the available capacity.

Upgrades to this system are planned for the 2012 time frame, which will increase data rates to 64 Kb/sec and the number of available channels to 64. The table below uses costs provided by the WSP based on a previous deployment with radio devices connected to portable DMS.

Figure 4 – Typical WSP Data Radio Schematic

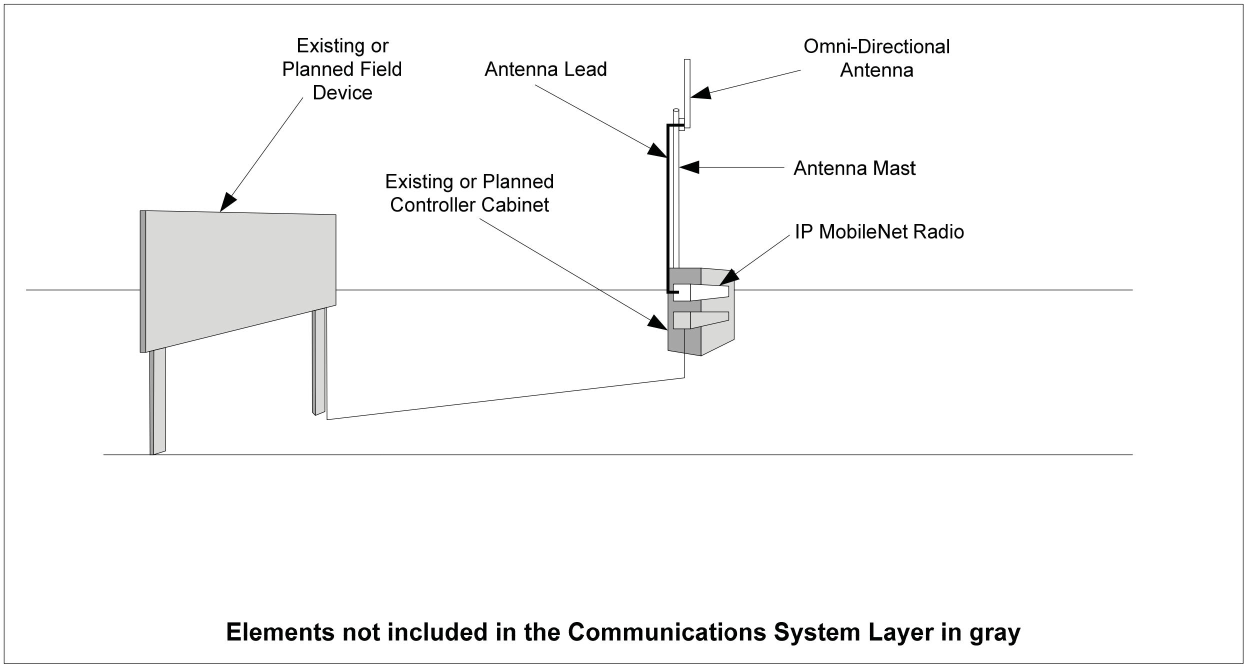


Table 5 - Typical WSP Data Radio Cost Assumptions

ITEM	Unit	Quantity	Unit Price	Total Cost	Assumptions
Radio	each	1	$2,200.00	$2,200.00	Per direction from WSP
Antenna	each	1	$40.00	$40.00	VHF Omni Mast
Antenna Lead	ft	50	$1.00	$50.00	LMR-400 or similar
Installation	each	1	$1,000.00	$1,000.00	10 person-hours assumed
			Total Install Cost	**$3,290.00**	

Commercial Telecommunications

In some cases, the most effective way (and perhaps the only feasible way) to provide data communications to a remote site is by contracting with a commercial telecommunications provider, such as a regional telephone company. These providers offer a wide variety of services, ranging from low-speed dial-up telephone connections (such as currently used on RWIS sites) to residential-level ISDN and DSL service, to high-capacity, high-reliability connections such as T-1, DS-3 and beyond.

These services cover a very wide range of performance and costs. The typical installation shown below is modeled on a DSL service; however location may affect these assumptions greatly.

Figure 5 – Typical Commercial Telecommunications Schematic

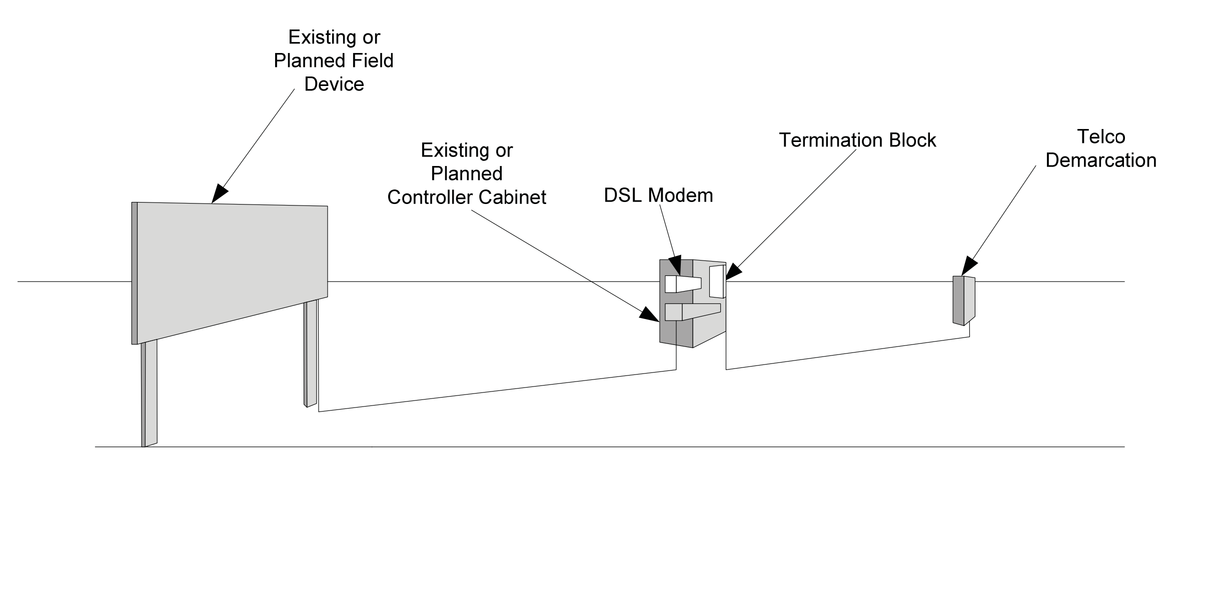


Table 6 - Typical Commercial Telecommunications Cost Assumptions

ITEM	Unit	Quantity	Unit Price	Total Cost	Assumptions
CPE (VDSL modem)	each	1	$1,100.00	$1,100.00	RS910L
Premises Termination (punch block/jack)	each	1	$30.00	$30.00	PX-66-25PR-PD
Installation (Telco)	each	1	$100.00	$100.00	Estimate based on $100 commercial install fee
Installation (Contractor)	each	1	$1,000.00	$1,000.00	
Recurring Cost	month	1	$200.00	$200.00	Representative Commercial DSL
			Total Install Cost	**$3,630.00**	Includes 1st month

3.6 Analysis and Assignment of Communications Methods

Assignment of communications methods followed a step-wise approach that begins with a calculation of costs for fiber optic connections to each location that required data service, then using that value to apply a series of decision rules to assign a communication method.

Note: The first three steps shown below are based on the geospatial database described in section 3.4. The values used in step 4 are described in detail in section 3.5, and the assumptions used in steps 7 and 8 are listed above in section 3.3.

1. Determine locations of all devices/users of data transport.
2. Determine locations of all fiber optic facilities available for use.
3. Determine locations of all points at which fiber facilities could be accessed.
4. Compute average costs for various communications methods (fiber, wireless broadband, WSP radio, cellular & DSL).
5. Compute required lengths of additional fiber optic cables between access points and devices.
6. Compute total costs if all connections were based on fiber optic installations.
7. Assume a maximum practical cost limit for fiber optic connections.
8. Using pre-determined assumptions, assign a non-fiber optic communication method for those devices exceeding the cost limit.
9. Aggregate costs for all devices.
10. Aggregate costs based on TOIP Corridor, priority or other parameter.

Keeping a fixed, repeatable approach to assignment allows for changes to be made in the underlying assumptions and re-analysis to reveal cost sensitivities to various inputs and to explore other mixtures of communication methods.

Ultimately, one of eight codes was assigned to each of the approximately 1,460 connection points. The codes used for the database consisted of:

1. Fiber Optic (to splice vaults/communications huts)
2. Wireless Broadband – point-to-point connections
3. Cellular Data Service
4. Wisconsin State Patrol Data Radio
5. Commercial Telecommunication Service (T1, DSL, etc.)
6. No Communication Method Required (for law enforcement pads, ramp closure gates, etc.)

7. Method to be determined (used for cases where fiber optic costs exceeded $100,000 and no other method was feasible).

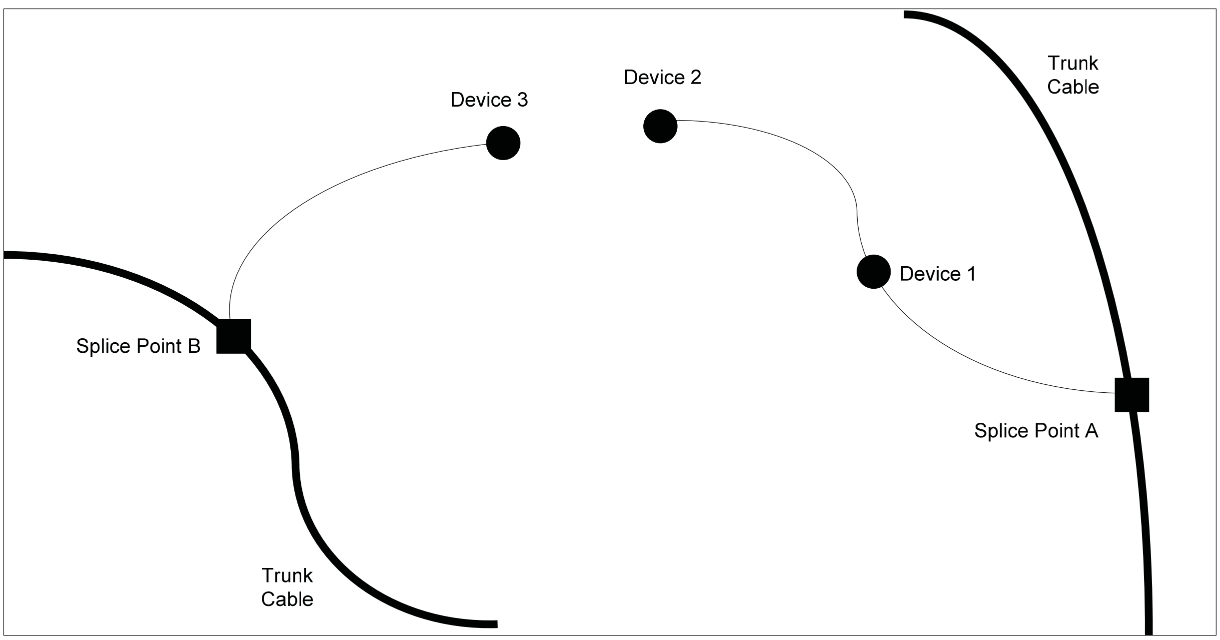
8. Fiber optic required (for cases where fiber optic costs exceed the maximum threshold but were less than $100,000 and no other method was feasible).

The assignment framework is extensible, as each point is assigned a numeric identifier to associate it with a communications method. Additional methods can be created and assigned as long as the decision rule is compatible with those used for other methods.

3.7 Output Checking and Corrections

Because the underlying software could only determine a path from a point to the nearest connection, a point-by-point check of the output was needed to ensure that realistic solutions would be generated. The most common case where the network model required adjustment was when a point would be routed to a splice point on a "trunk" cable or a communications hut when simply connecting it to an adjacent point would be more economical. This condition is illustrated in Figure 6 below.

Figure 6 - Improper Fiber Optic Routing Example



In this example, a fiber optic "branch" extends from Splice Point A to Device 1 and then on to Device 2. Because Device 3 is closer to Splice Point B than Splice Point A, a second branch is computed for the connection. In reality, the total amount of fiber optic cable would be less if all points connected via a single branch to Point A. These conditions were identified and corrected by deleting the initial "computed" segment and manually adding a connection between Devices 2 and 3.

After these and similar topological corrections were made, a final determination for communication method was made for analysis purposes.

3.8 Database Creation and Summarization

After corrections to the underlying network were completed, a full application of the decision process and the data associated with each point was exported to Microsoft Excel for summarization. A variety of reporting products were produce from this process, which are presented in sections 4.2 and 4.3.

3.9 Summary

The CSL project followed a data-driven, rules-based approach to planning for eventual data connections to roadside devices and fixed operations and service centers for the entire State of Wisconsin. Because the rules approach used simplifying assumptions to enable analysis, full checking of the outputs was completed. The similarity of results before and after checking as well as under differing assumptions support the viability of this approach for planning purposes.

Making assumptions to treat entire classes of devices inevitably introduces conditions where the planned connection method and associated costs may require revision to meet real-world conditions at a specific site. For this reason, the CSL is best used as a planning an programming aid, rather than a specific design recommendation.

4.0 Analysis Products

4.1 Overview of Product Types

Because of the large number of individual connections, the products created by the project took two distinct forms: electronic data files and summary tables. The schematic design described in the following section includes both technical data regarding the communications method, cost information and geospatial information showing position and (where applicable) fiber optic connectivity. Given the difficulties in representing such a large number of data points over a large geographic area, the schematic design will be represented in a geo-database supplied to WisDOT and accessible through a variety of software tools.

4.2 Communications Schematic Design

Several iterations of the schematic design were completed as part of the plan development process. These are indicated in the database files as codes in the "Method" field. Each Method was based on different base data and assumptions as listed below:

- **Method 1**: The first pass using initial assumptions and an underlying fiber network that had not been reviewed with the Project Management Team.
- **Method 2**: A second pass to establish baseline fiber optic costs to all points using the revised network.

- **Method 3**: Third iteration using initial assumptions with the revised network. This provided a basis for comparison with the revised assumptions.

- **Method 4**: The final iteration used the revised network and revised assumptions. Points that did not require data connections (law enforcement pads, ramp closure gates, etc.) were removed from the analysis to ensure more accurate distances were computed to "true" connection sites.

For planning purposes, Method 4 represents the most complete "preferred" iteration. This includes a variety of fiber optic and wireless communication connections that create cost-effective hybrid network for connecting not only WisDOT's roadside devices, but also a variety of partner agencies and fixed centers.

In addition, roughly 90 Kilometers of fiber optic interconnections were identified that would connect project segments into continuous runs to facilitate communications redundancy and path flexibility. These segments are referred to as "Continuity Fiber" in the cost estimates. While these are not strictly necessary for device interconnection, their inclusion represents good practice for network design.

4.3 Cost Estimates

Several different aggregations of cost data were completed to illustrate the budget implications of including different types of devices or connections to centers. Table 7 shows a summarization that illustrates the costs for each of the methods described in section 4.2 for each of the connections to be made.

Method 4 shows higher aggregate costs than Method 3. This is due in large part to changing the assumption that the maximum allowable cost for a fiber optic connection to a TOIP site from $40,000 to $50,000 (thus reducing the number of connections using lower cost wireless links) and a revision to the assumption of availability of cellular connections in northern Wisconsin, which required higher-cost State Patrol data radio solutions.

To relate the CSL directly to the TOIP corridors and the deployments projected under that planning process, the cost estimates were also aggregated specifically for TOIP devices, as shown in Table 8.

Table 7 - Costs by Connected Entity

CSL Component	Method 2 Cost Estimate	Method 3 Cost Estimate	Method 4 Cost Estimate
TOIP Elements	$34,975,465.00	$12,038,708.79	$12,653,047.63
CCTV Sites	$11,732,346.97	$6,988,398.67	$7,834,315.43
Non-CCTV Sites	$23,243,118.04	$5,050,310.13	$4,818,732.20
Automatic Traffic Recorders	$24,485,757.13	$330,474.48	$363,634.46
DMV Centers	$20,306,367.17	$20,306,367.17	$20,889,765.03
Highway Advisory Radio Sites	$163,806.48	$62,282.61	$62,282.61
Public Safety Answering Points	$37,551,842.93	$37,551,842.93	$37,726,569.74
Rest Areas	$1,000,522.93	$1,000,522.93	$1,000,522.93
Safety and Weight Enforcement Facilities	$789,688.14	$789,688.14	$1,246,337.92
Level 1 Trauma Centers	$65,135.09	$65,135.09	$65,135.09
U of W Campuses	$2,683,431.96	$2,683,431.96	$2,683,431.96
Road Weather Information Systems	$14,185,147.99	$191,115.81	$201,113.70
Non-TOIP DMS	$487,192.18	(1)	$24,035.75
Continuity Fiber (89364 meters)	$3,148,043.50	$3,148,043.50	$3,148,043.50
Total Cost / Method	**$139,842,400.51**	**$78,167,613.42**	**$80,063,920.31**

(1) Several DMS were added manually by the PMT and included in the Method 4 calculations.

Table 8 - Cost Breakdown by TOIP Corridor

TOIP Corridor	Cost Breakdown	Method 2 Cost	Method 3 Cost	Method 4 Cost
Badger State	**Corridor Total**	**$3,513,912.95**	**$1,846,732.42**	**$2,036,939.31**
	CCTV Sites	$1,521,145.47	$1,237,704.58	$1,384,850.36
	Non-CCTV Sites	$1,992,767.48	$609,027.84	$652,088.94
Capitol	**Corridor Total**	**$2,684,206.96**	**$1,081,053.00**	**$1,434,245.16**
	CCTV Sites	$1,303,793.90	$390,250.61	$589,345.37
	Non-CCTV Sites	$1,380,413.06	$690,802.38	$844,899.79
Fox Valley	**Corridor Total**	**$5,944,625.23**	**$1,923,362.12**	**$1,850,655.49**
	CCTV Sites	$2,681,494.46	$1,409,644.53	$1,389,577.24
	Non-CCTV Sites	$3,263,130.76	$513,717.59	$461,078.25
South Central Connection	**Corridor Total**	**$2,475,908.52**	**$1,188,161.41**	**$961,275.03**
	CCTV Sites	$1,388,444.86	$754,879.41	$728,540.25
	Non-CCTV Sites	$1,087,463.66	$433,282.01	$232,734.78
Hiawatha	**Corridor Total**	**$2,165,344.52**	**$1,539,563.87**	**$1,773,215.17**
	CCTV Sites	$1,208,467.81	$835,116.17	$934,726.61
	Non-CCTV Sites	$956,876.71	$704,447.69	$838,488.56
Wisconsin River	**Corridor Total**	**$3,896,374.91**	**$552,711.76**	**$616,946.24**
	CCTV Sites	$539,680.70	$348,513.48	$389,671.07

TOIP Corridor	Cost Breakdown	Method 2 Cost	Method 3 Cost	Method 4 Cost
	Non-CCTV Sites	$3,356,694.21	$204,198.27	$227,275.16
Chippewa Valley	**Corridor Total**	**$1,545,910.44**	**$539,150.88**	**$581,647.09**
	CCTV Sites	$926,404.91	$422,208.79	$464,705.01
	Non-CCTV Sites	$619,505.54	$116,942.09	$116,942.09
Wild Goose	**Corridor Total**	**$2,951,828.00**	**$727,474.98**	**$775,890.62**
	CCTV Sites	$349,559.51	$210,939.05	$290,330.37
	Non-CCTV Sites	$2,602,268.49	$516,535.93	$485,560.26
Peace Memorial	**Corridor Total**	**$180,856.44**	**$134,779.27**	**$165,003.83**
	CCTV Sites	$69,855.54	$69,855.54	$100,080.10
	Non-CCTV Sites	$111,000.91	$64,923.73	$64,923.73
Cornish Heritage	**Corridor Total**	**$581,319.25**	**$ 18,858.60**	**$ 18,858.60**
	CCTV Sites	$ 8,806.80	$ 8,806.80	$ 8,806.80
	Non-CCTV Sites	$572,512.45	$10,051.80	$10,051.80
Titletown	**Corridor Total**	**$5,014,944.19**	**$1,109,749.76**	**$1,047,026.22**
	CCTV Sites	$671,536.11	$382,706.88	$595,104.11
	Non-CCTV Sites	$4,343,408.08	$727,042.88	$451,922.11
Southern Tier	**Corridor Total**	**$550,636.36**	**$508,316.28**	**$550,636.36**
	CCTV Sites	$481,661.51	$481,661.51	$481,661.51
	Non-CCTV Sites	$68,974.86	$26,654.77	$68,974.86
Glacial Plains	**Corridor Total**	**$2,703,159.03**	**$591,381.85**	**$484,397.76**
	CCTV Sites	$498,359.20	$399,381.56	$440,186.88
	Non-CCTV Sites	$2,204,799.83	$192,000.29	$44,210.89
Coulee Country	**Corridor Total**	**$766,438.19**	**$277,412.61**	**$356,310.74**
	CCTV Sites	$83,136.19	$36,729.75	$36,729.75
	Non-CCTV Sites	$683,302.00	$240,682.86	$319,580.99
Total ITS Element Cost by Method		**$34,975,465.00**	**$12,038,708.79**	**$12,653,047.63**

The following tables delineate the types of communication media used by connected entity. Note that for the connected centers (DMV Service Centers, etc.) only fiber optic connections were considered to be appropriate for the data requirements, and therefore no costs appear for these in most tables.

Table 9 - Fiber Optic Cable Cost (Method 1 - within maximum cost)

CSL Component	Method 2 Cost	Method 3 Cost	Method 4 Cost
ITS Elements	$34,975,465.00	$6,345,052.81	$8,445,015.79
CCTV Sites	$11,732,346.97	$2,664,233.14	$3,799,252.58
Non-CCTV Sites	$23,243,118.04	$3,680,819.67	$4,645,763.20
Automatic Traffic Recorders	$24,485,757.13	$249,549.48	$242,609.46
DMV Centers	$20,306,367.17	$20,306,367.17	$20,889,765.03
Highway Advisory Radio Sites	$163,806.48	$58,547.61	$58,547.61
Public Safety Answering Points	$37,551,842.93	$37,551,842.93	$37,726,569.74
Rest Areas	$1,000,522.93	$1,000,522.93	$31,880.62
Safety and Weight Enforcement Facilities	$789,688.14	$789,688.14	$1,024,688.37
Level 1 Trauma Centers	$65,135.09	$65,135.09	$65,135.09
U of W Campuses	$2,683,431.96	$2,683,431.96	$2,683,431.96
Road Weather Information Systems	$14,185,147.99	$157,500.81	$147,848.70
Non-TOIP DMS	$487,192.18	$--	$13,139.75
Continuity Fiber (89364 meters)	$3,148,043.50	$3,148,043.50	$3,148,043.50
Total Cost (Code 1) / Method	**$139,842,400.51**	**$72,355,682.44**	**$74,476,675.61**

Table 10 - Wireless Broadband Cost (Method 2)

CSL Component	Method 2 Cost	Method 3 Cost	Method 4 Cost
ITS Elements	$--	$588,384.00	$408,600.00
CCTV Sites	$--	$365,016.00	$283,296.00
Non-CCTV Sites	$--	$223,368.00	$125,304.00
Automatic Traffic Recorders	$--	$--	$--
DMV Centers	$--	$--	$--
Highway Advisory Radio Sites	$--	$--	$--
Public Safety Answering Points	$--	$--	$--
Rest Areas	$--	$--	$--
Safety and Weight Enforcement Facilities	$--	$--	$--
Level 1 Trauma Centers	$--	$--	$--
U of W Campuses	$--	$--	$--
Road Weather Information Systems	$--	$--	$--
Non-TOIP DMS	$--	$--	$10,896.00
Total Cost (Code 2) / Method	**$0.00**	**$588,384.00**	**$419,496.00**

Table 11 - Cellular Data Cost (Method 3)

CSL Component	Method 2 Cost	Method 3 Cost	Method 4 Cost
ITS Elements	$--	$22,410.00	$41,085.00
CCTV Sites	$--	$--	$--
Non-CCTV Sites	$--	$22,410.00	$41,085.00
Automatic Traffic Recorders	$--	$80,925.00	$58,515.00
DMV Centers	$--	$--	$--
Highway Advisory Radio Sites	$--	$3,735.00	$3,735.00
Public Safety Answering Points	$--	$--	$--
Rest Areas	$--	$--	$--
Safety and Weight Enforcement Facilities	$--	$--	$--
Level 1 Trauma Centers	$--	$--	$--
U of W Campuses	$--	$--	$--
Road Weather Information Systems	$--	$33,615.00	$23,655.00
Non-TOIP DMS	$--	$--	$--
Total Cost (Code 3) / Method	**$0.00**	**$140,685.00**	**$126,990.00**

Table 12 - Wisconsin State Patrol Data Radio Cost (Method 4)

CSL Component	Method 2 Cost	Method 3 Cost	Method 4 Cost
ITS Elements	$--	$--	$6,580.00
CCTV Sites	$--	$--	$--
Non-CCTV Sites	$--	$--	$6,580.00
Automatic Traffic Recorders	$--	$--	$62,510.00
DMV Centers	$--	$--	$--
Highway Advisory Radio Sites	$--	$--	$--
Public Safety Answering Points	$--	$--	$--
Rest Areas	$--	$--	$--
Safety and Weight Enforcement Facilities	$--	$--	$--
Level 1 Trauma Centers	$--	$--	$--
U of W Campuses	$--	$--	$--
Road Weather Information Systems	$--	$--	$29,610.00
Non-TOIP DMS	$--	$--	$--
Total Cost (Code 4) / Method	**$0.00**	**$0.00**	**$98,700.00**

Methods five and six are not shown. Method five (commercial telecommunications provider) was not used under any of the planning iterations. It may be assigned on a case-by-case basis during revisions to the CSL. Code six was used for locations that did not have a data requirement, but appeared in the TOIP documents (such as law enforcement pads). Since no data connection was required there was no associated cost.

The following tables represent costs associated with connections deemed necessary, but exceed the limits established in the assumptions. The code seven summarizes total cost for connections that exceed $100,000 per link. These should be reviewed for alternatives and may be candidates for commercial telecommunications connections. Code eight represents connections that fall into a "gray" area, where costs exceed the $50,000 maximum assumed, but are less than $100,000.

Table 13 - Individual Connections Exceed $100,000 (Method 7)

CSL Component	**Method 2 Cost**	**Method 3 Cost**	**Method 4 Cost**
ITS Elements	$--	$1,595,580.80	$1,595,580.80
CCTV Sites	$--	$1,595,580.80	$1,595,580.80
Non-CCTV Sites	$--	$--	$--
Automatic Traffic Recorders	$--	$--	$--
DMV Centers	$--	$--	$--
Highway Advisory Radio Sites	$--	$--	$--
Public Safety Answering Points	$--	$--	$--
Rest Areas	$--	$--	$302,636.88
Safety and Weight Enforcement Facilities	$--	$--	$221,649.54
Level 1 Trauma Centers	$--	$--	$--
U of W Campuses	$--	$--	$--
Road Weather Information Systems	$--	$--	$--
Non-TOIP DMS	$--	$--	$--
Total Cost (Code 7) / Method	**$0.00**	**$1,595,580.80**	**$2,119,867.21**

Table 14 - Individual Connections between $50,000 and $100,000 (Method 8)

CSL Component	Method 2 Cost	Method 3 Cost	Method 4 Cost
ITS Elements	$--	$3,487,281.19	$1,786,582.05
CCTV Sites	$--	$2,363,568.73	$1,786,582.05
Non-CCTV Sites	$--	$1,123,712.45	$--
Automatic Traffic Recorders	$--	$--	$--
DMV Centers	$--	$--	$--
Highway Advisory Radio Sites	$--	$--	$--
Public Safety Answering Points	$--	$--	$--
Rest Areas	$--	$--	$666,005.44
Safety and Weight Enforcement Facilities	$--	$--	$--
Level 1 Trauma Centers	$--	$--	$--
U of W Campuses	$--	$--	$--
Road Weather Information Systems	$--	$--	$--
Non-TOIP DMS	$--	$--	$--
Total Cost (Code 8) / Method	**$0.00**	**$3,487,281.19**	**$2,452,587.49**

4.4 Data Management Tools

To input, analyze and present the volume of data needed for the CSL, two software packages were employed.

ArcGIS provided the database engine and interfaces for entering data and assigning attributes to each point and line feature created. The Network Analyst module enabled the route-based approach to automatically determining the shortest path along state roadways to the nearest splice point. The process of identifying points for potential wireless connections based on location properties was also enabled by the spatial analysis tools in ArcGIS. Figure 7 below shows the editing interface used to create the TOIP dataset. Figure 8 shows the Network Analyst interface used for routing fiber optic connections and determining distances.

Figure 7 - ArcGIS Data Editing (adding splice locations)

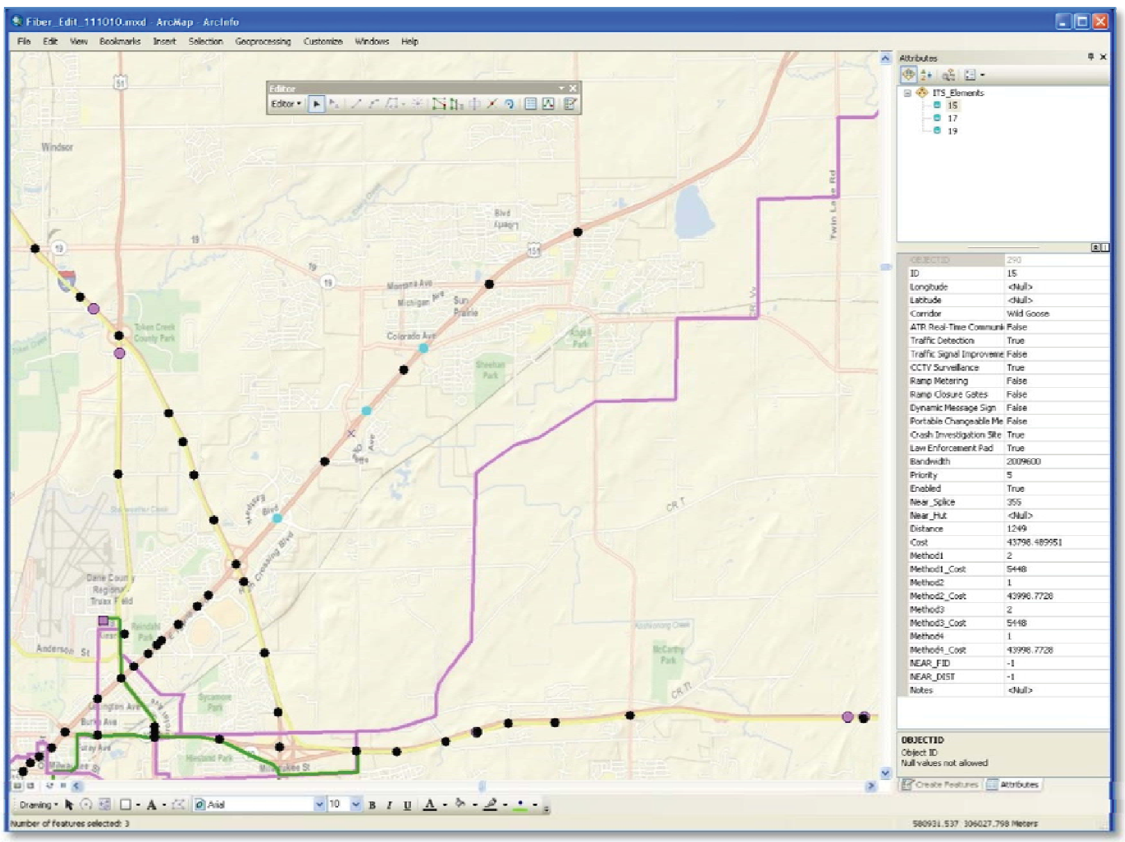
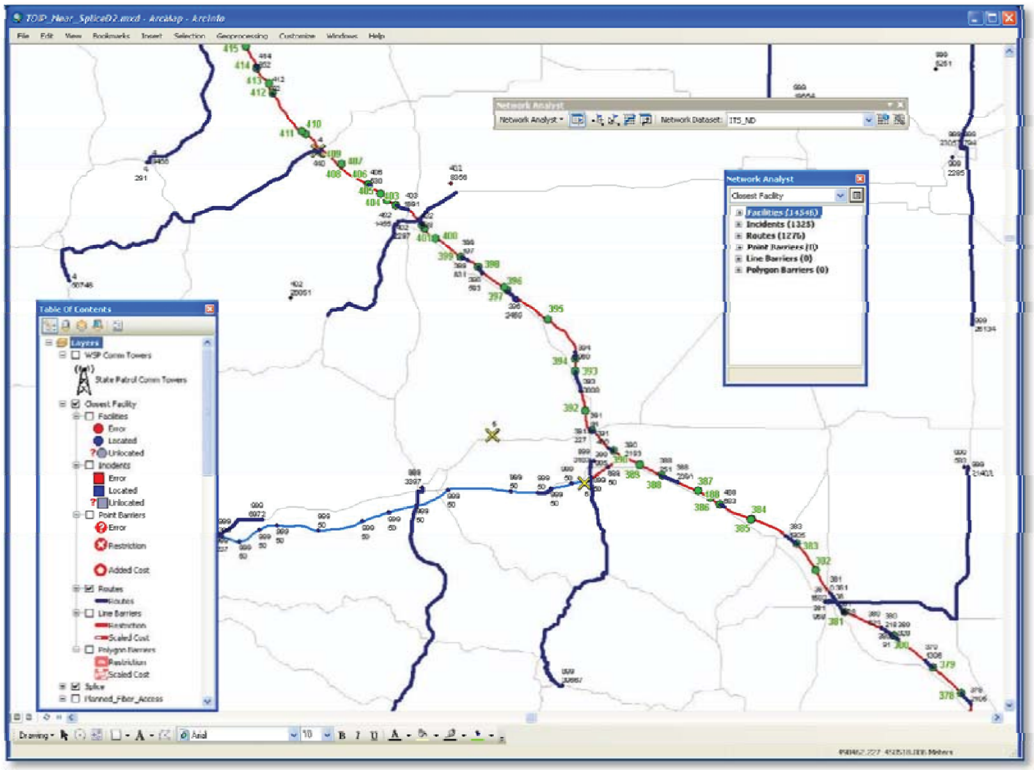


Figure 8 - ArcGIS Network Analyst Tool

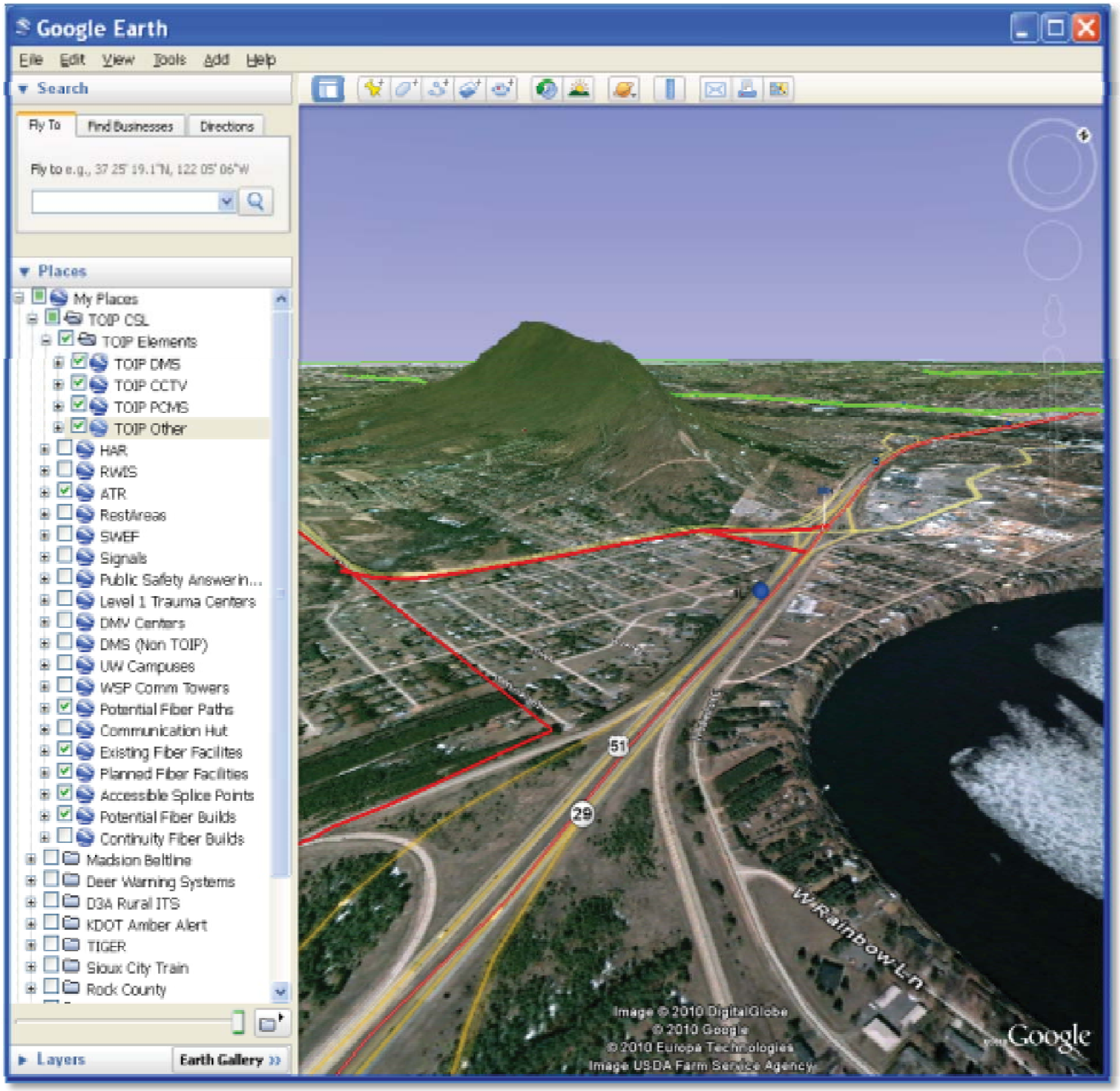


While ArcGIS is an extremely powerful application for manipulating and analyzing data, its cost and steep learning curve limits its usefulness as a general purpose data visualization tool. For this reason, data was converted for use with Google's Earth application. This software is available without charge from Google, and while it does not provide tools to query or summarize data, it does provide an exceptionally easy to use interface for viewing large data sets. The process for preparing the data involved several steps, but was easily accomplished with tools available in ArcGIS. The process can be summarized as follows:

1) Determine what data is to be exported from the project's geo-database.
2) Select the data and convert it to a "layer" - an extract from the database representing one feature type (RWIS, CCTV site, etc.).
3) Export the layer to a Keyhole Markup Language (KML) file for use with Google Earth.
4) Open the files in Google Earth.
5) Adjust the labels or symbols as needed.
6) If desired, move the items into the "My Places" folder in Google Earth. This will preserve any changes made and make the data available every time Earth is opened.

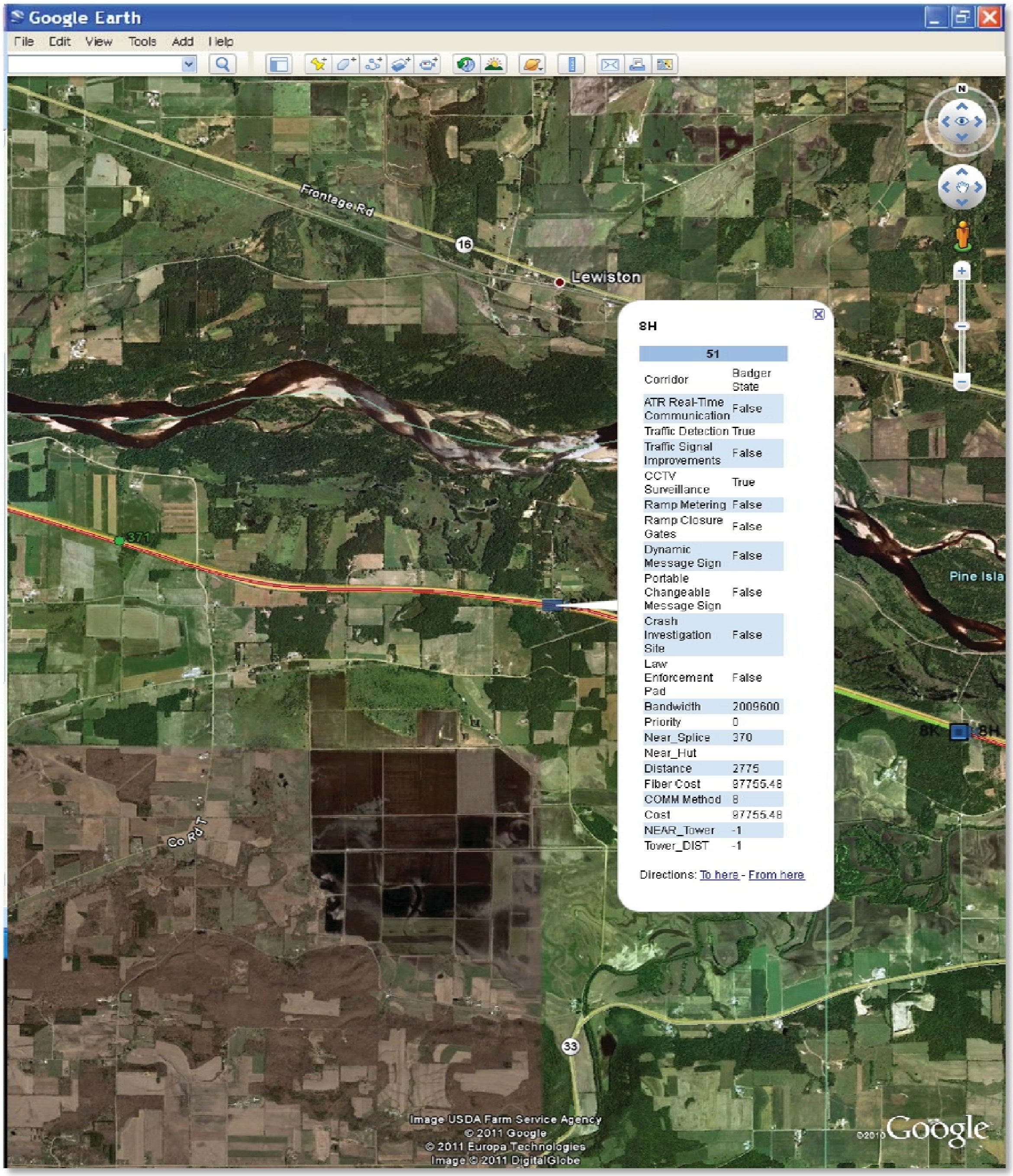
As shown below, users can view and manipulate data in a three-dimensional view with satellite imagery for any place in the State.

Figure 9 - Google Earth Interface (3D)



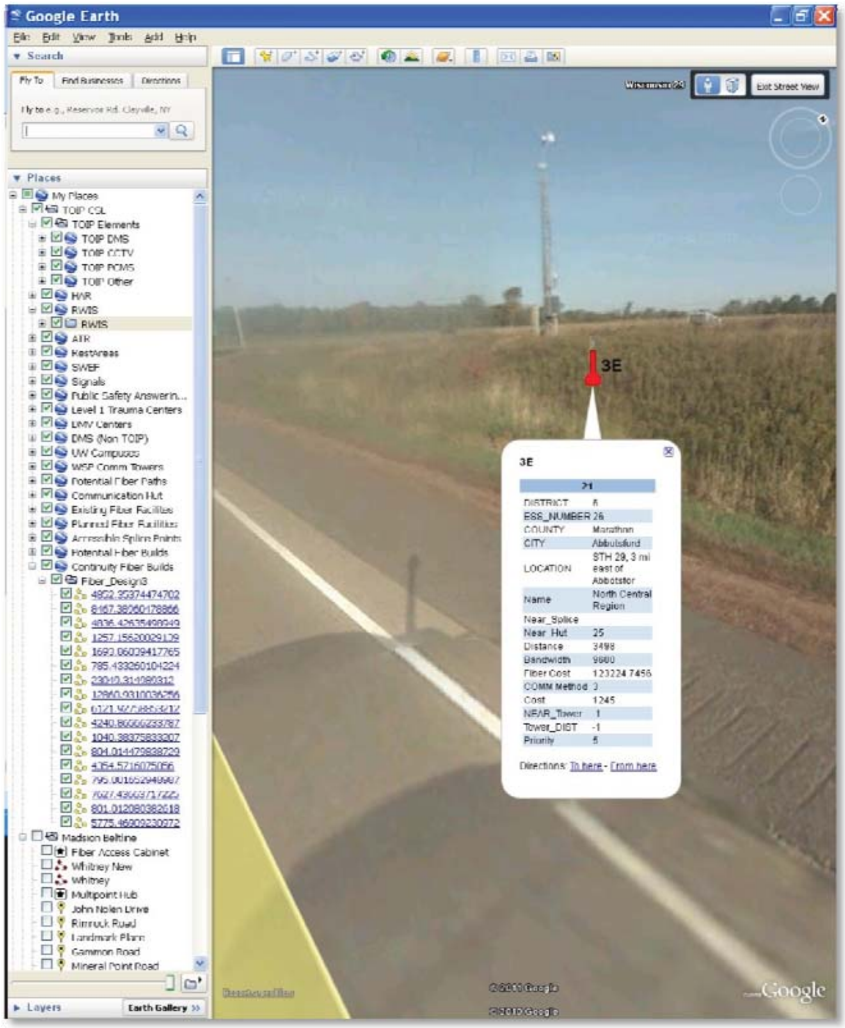
The attributes of each data element are preserved with the transfer between ArcGIS and Earth, which allows for users to review specific information (including projected cost and communication methods) for each point as shown in Figure 10.

Figure 10 - Point Attributes in Google Earth



In addition, the Google Street View feature allows users to view images of projected and existing deployment sites with ground level imagery. Figure 11 shows and existing RWIS site, along with the point data and symbology from the spatial database.

Figure 11 - Street Level Imagery in Google Earth



4.5 Prioritization

In consultation with the Project Management Team, deployment priorities were defined using a corridor-based approach to provide a view of how CSL costs would occur over time. Four categories of priority were defined on a three-year interval basis. Under this scheme, Priority 1 represented years 0-3, Priority 2 years 4-6, Priority 3 years 6-9, and Priority 4 ten years and beyond.

Due to the way the priorities are defined along corridors, connections to fixed-location centers are not included; only the TOIP, ATR and RWIS point locations receive priority coding. Also, the exclusion of the I-94 corridor (as much of the infrastructure is already in place) and other roadways that do not fall along TOIP corridors further reduce the number of points included in the estimates by priority.

Figure 12 shows the locations of the corridors and the time horizons used for each. Table 15 lists the total dollar amounts summarized by priority and device type.

Figure 12 - CSL Priority Corridors

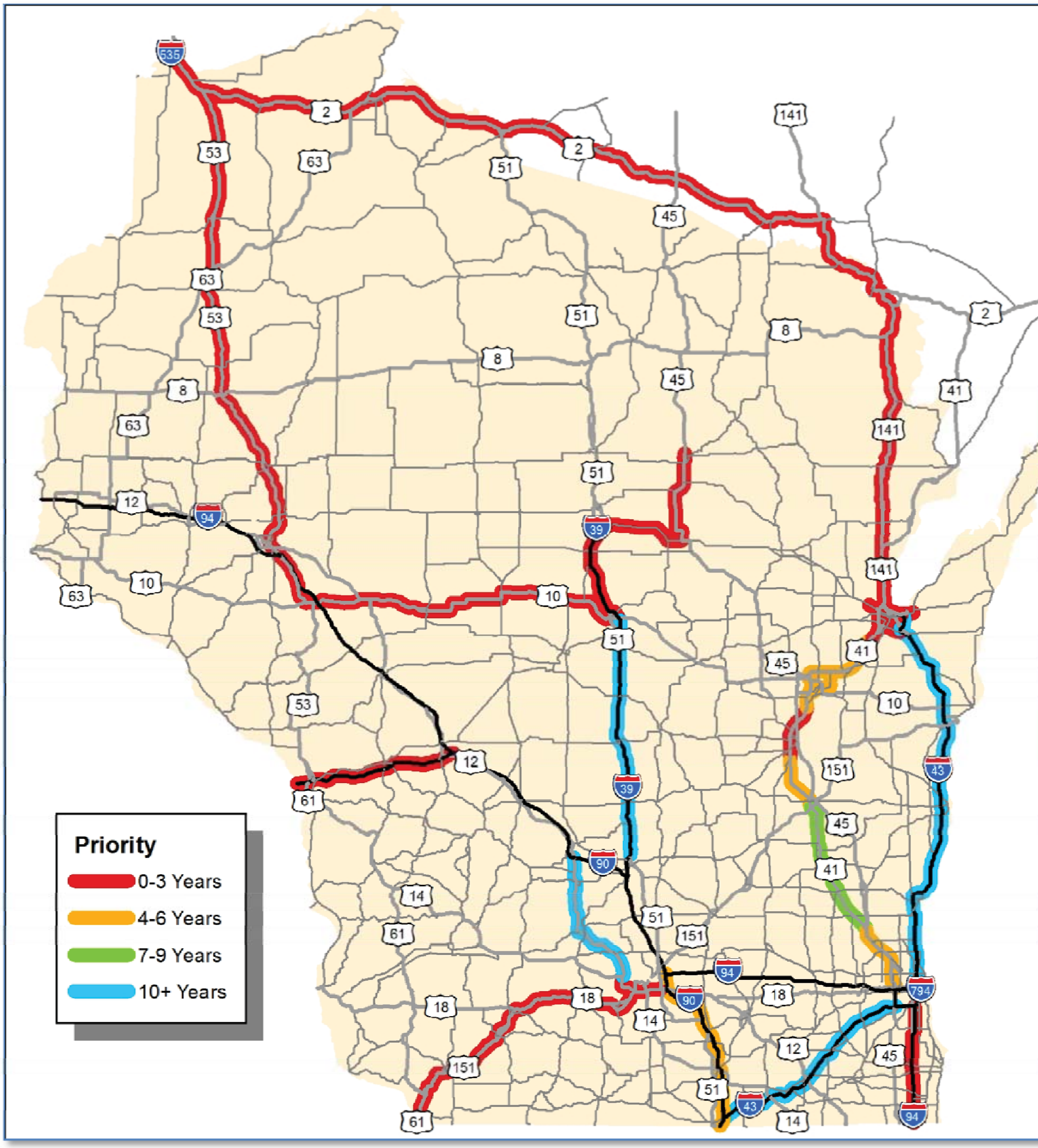


Table 15 - Total Costs by Priority

Method 4 – Revised Assumptions/Revised Base Data				
CSL Component	**Priority 1**	**Priority 2**	**Priority 3**	**Priority 4**
ITS Elements	$1,608,823.93	$2,149,942.59	$523,381.29	$1,605,600.08
CCTV Sites	$792,245.71	$1,737,887.31	$310,832.60	$1,277,078.27
Non-CCTV Sites	$816,578.21	$412,055.28	$212,548.69	$328,521.80
ATR	$83,988.04	$13,117.48	$34,182.43	$60,275.57
RWIS	$45,173.32	$15,207.02	$1,245.00	$15,231.12
Method 4 Cost / Priority	**$1,737,985.28**	**$2,178,267.09**	**$558,808.72**	**$1,681,106.76**

4.6 Short-Term Recommendations

Short-term recommendations are included as a deliverable of the TOIP CSL project and identify key programs or installation components that should be addressed in the short-term to move the ITS communications infrastructure forward. The two main short-term recommendations are conducting pre-design for near-term fiber optic installations and exploring "Green" Energy opportunities with the communications infrastructure and how it is powered. Each is discussed in further detail in the following text and where appropriate in the attached appendix.

Pre-Design for Near-Term Fiber Installations

Several projects have recently received funding grants to install long segments of new fiber optic infrastructure. These are planned to be installed along the following roadways:

- USH 2/USH 141 (Superior to Green Bay)
- USH 53 (Eau Claire to Superior)
- USH 10 – Eau Claire to Stevens Point
- I-39 – Stevens Point to Wausau
- STH 29 – Rothschild to Wittenberg
- USH 45 – Wittenberg to Antigo
- USH 151 (Madison to Platteville)

Since these installations all fall along State jurisdiction roadways, an opportunity exists to negotiate optimal access locations to minimize construction complexity and costs for TOIP and other potential deployments. As these locations must be determined prior to the design of the fiber facility itself, the desired locations must be identified and communicated to the project managers.

The affected points may be easily identified using a spatial query and can then be field-verified and a preliminary pre-design completed to produce a list of locations along each route where access to the fiber optic cable is desired.

Environmental "Green" Opportunities

In addition to utilizing the expanding capabilities of new ITS technologies, there has been an increasing interest in minimizing the energy consumed by deployments. Increasing energy cost along with a desire to minimize various forms of pollution (commonly called a "carbon footprint) that result from fossil-fuel based generation have resulted in a variety of alternative energy sources available for use in deployment.

5.0 Future Applications

The flexibility and portability of the data underlying the CSL means a number of applications beyond the immediate recommendations of this report are possible. This section outlines several that may be of immediate interest to stakeholders.

5.1 Database Housing and Maintenance

Data is currently stored in an ArcGIS geo-database, which provides a flexible management structure for using analysis and editing tools. However, the ArcGIS software may not be an ideal solution for the maintenance of the data in the future. A suitable long-term host for the data should be identified and the data converted to a format that can be easily integrated with other initiatives.

The University of Wisconsin currently has a partnership with WisDOT for the maintenance of inventory data for ITS deployments. Expansion of this role may be a logical means for future use of the CSL data.

5.2 Integration with Asset Management Systems

To further the use of CSL data with work being done by the University, an integration of the projected communications deployments with the asset management system being deployed now should be explored. A system whereby planned elements from the TOIP are gradually revised and added to the existing assets in the system would provide a unique view into the progression of ITS deployment and the expansion of the underlying communications networks.

5.3 User Tools and Data Hosting

While the ability to track the attributes of the thousands of data points and create analysis summaries for planning purposes is extremely useful, during the development of the CSL it was discovered that a number of stakeholders saw "live" access to the data as valuable for a variety of applications. To offer consistent, useful access to the database, two elements must come together:

1) A consistent user interface must be made available. During the CSL development process, Google Earth was used for presentation. Google Earth combines low cost with very good performance and an intuitive user interface. For these reasons, it should be considered as the "standard" way for non-maintainers to visualize the spatial data from the CSL.

2) Data must be distributed and versions controlled. Ensuring that all users are accessing a common data set is a key element in ensuring its usefulness. Several options are available for enabling version control, the simplest of which may be the "network data" source functionality in the Keyhole Markup Language used by Google Earth products. Using this tool data may be edited and analyzed with any suitable tool, then exported to a single location. Earth clients then access this location across the network, so that a single source exists for all users.

5.4 Geospatial Enhancements and Topology Analysis

The use of network analysis tools offers the ability to do powerful analysis through future enhancements. While the initial scope of the CSL limited the opportunities to explore some complex analyses, future efforts may be able to make use of the topological aspects of the underlying roadway and fiber optic networks.

Using these features, the data networks could include concepts of "connectedness" and directionality of data flows. This would eliminate the need to hand-verify all of the analysis outputs since each point would need a valid path to a data "destination". Assessing various connection scenarios would be much more efficient since changing a connection method could not "orphan" one or more upstream devices via a broken link. These cases would be automatically identified and (if desired) corrected by the system.

Since data needs are an attribute of each point to be connected, a topology-enabled network could also project aggregate bandwidth needs at any point on the network and identify when any arbitrary capacity limit is reached. Using these tools, needed upgrades to both the network branches supporting ITS connections, as well as the core ITSNET may be projected based on the planned deployment of devices.

Appendix A

Green Energy Layer Analysis

Overview

In addition to utilizing the expanding capabilities of new ITS technologies, there has been an increasing interest in minimizing the energy consumed by deployments. Increasing energy cost along with a desire to minimize various forms of pollution (commonly called a "carbon footprint) that result from fossil-fuel based generation have resulted in a variety of alternative energy sources available for use in deployment.

Environmental "Green" Opportunities

In addition to utilizing the expanding capabilities of new ITS technologies, there has been an increasing interest in minimizing the energy consumed by deployments. Increasing energy cost along with a desire to minimize various forms of pollution (commonly called a "carbon footprint) that result from fossil-fuel based generation have resulted in a variety of alternative energy sources available for use in deployment.

Advantages of "Green" Alternatives

Several aspects of green energy designs may offer substantial advantages over traditional commercial power. Although reliability of the system must be carefully planned, the following advantages are characteristic of green designs:

Reduced Installation Costs

Installation costs can be reduced in cases where very long runs of new electrical cable is needed or installation is particularly difficult (such as boring through rocky soils or very deep to avoid surface water/wetlands). Difficult commercial power installs can dramatically increase project costs, making alternatives more attractive.

In addition to the wiring, some systems in remote locations may require more than one power service to be installed due to ground conditions that can limit the ability to install wiring. Each of these would result in separate charges from the utility company both for installation and service.

Systems that do not rely on a commercial connection avoid these costs and minimize recurring costs and installation time.

Greater System Flexibility

Without the need for in-ground or overhead cables, installation can avoid many of the concerns associated with avoiding existing utilities. The lack of physical connections to commercial power also enables selection of sites that would otherwise be impractical due to installation costs.

Decreased Emissions

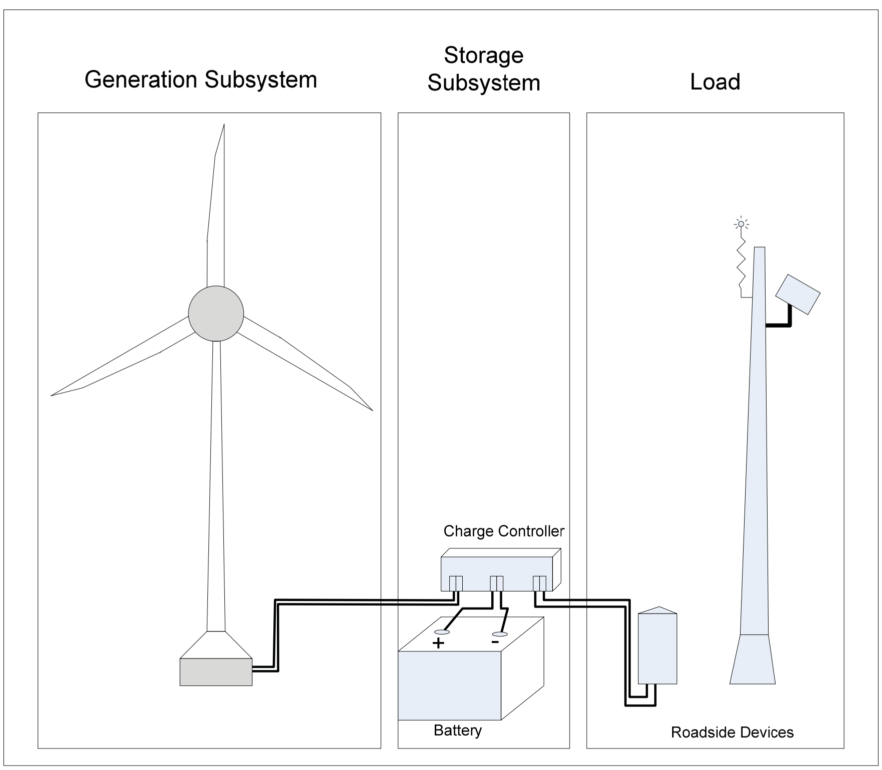
Depending on the specific power source used, emissions of greenhouse gases and other pollutants can be substantially reduced over the life of the system. The entire life-cycle of energy use and related emissions can be a complex data analysis exercise, but in general there is consensus that using a wind or solar generation system will yield lower overall emissions than any commercial power alternative except nuclear.

A small but significant reduction in vehicle emissions resulting from roadside ITS deployments and the associated management systems is also likely to result. A variety of studies have been conducted in the United States to gauge the impact of ITS-based surveillance, detection, monitoring, management and incident response on emissions and fuel consumption. Elements such as improved incident response due to better situational awareness and decreased congestion can decrease vehicle emissions (through decreased fuel consumption) by 1.4 to 5 percent. More specific benefits for projected deployment in Wisconsin were calculated as part of the TOIP project. This substantial benefit should also be considered during deployments.

Approaches to "Green" Energy Planning

To take full advantage of the unique features of green energy systems, careful planning at all levels of system design is needed. Some elements may also have safety or regulatory concerns that should be addressed prior to any deployments. When planning for green deployments, systems may be divided into Generation, Storage and Load subsystems, as shown in the diagram below. Each should be addressed in developing an overall approach to green power usage.

Figure A-1 - Subsystem Diagram



Managing and Minimizing Load Power Budget

Since alternative power generation systems usually have operational characteristics, such as variable outputs or lower overall output than a conventional commercial power source, minimizing power demands is a crucial first step in implementing green energy systems.

Peak Vs Average Power Draw

Many devices (such as wireless data radios) have an unavoidably high power demand when they are actually transmitting data. This is largely dictated by the natural attenuation of signals as they travel through the atmosphere. Similar situations occur when devices must access data storage media, activate lights or any other periodic action.

However, it is important to differentiate between these "peak" energy needs and the overall average, generally on a daily basis. For the example of a wireless system, even though the transmit power demand might be two watts, if it only transmits once per day and for one minute to transfer stored data, the average demand and therefore generation and storage subsystems, would be much smaller and less expensive than those required to support a continuous two-watt demand.

Power Budget

Using the concepts of peak and average power draw, it is possible to construct a "power budget" for daily requirements. This can then guide decisions on whether a green system is viable, and the technology and capacity needed.

The table below shows an example of a simplified power budget.

Table A-1 - Power Budget Example

Device Type	Model	Average Power Draw (Watts)	Daily Capacity Needed (Watt-Hours)
Vehicle Detector	G4	3	72
Cellular Modem	BT-6600	2	48
Charge Controller	SS-6L	0.1	2.4
	Total	**5.1**	**122.4**

In this example, the system requires over 122 watt-hours per day, assuming 100 percent efficiency in storage and no losses in the generation system. Real-world implementation would require inclusion of values for losses and assumptions about variability in the generation system. Additionally, the limitations of various generation technologies must be accounted for in a system design. These will be treated in detail in the Alternative Generation Technologies section.

Component Selection

As the continuous (or average) power draw of devices has a large impact on the sizing of generation and storage subsystems, it is advisable to begin considering average power draw as part of the design and procurement process. This adds an additional dimension to the usual criteria for selecting devices, which may conflict with some functional needs. Nevertheless, as opportunities arise to evaluate and select ITS devices that can minimize power draw.

Sleep Modes and Other Considerations

One aspect of component selection that requires analysis to be properly included is the use of "sleep" or other power-saving modes. These modes drastically reduce consumption during "idle" periods when a device is on, but not actively performing some task. A device that has higher peak consumption but a lower sleep mode figure may be a better choice based on the anticipated usage pattern. In the example below, a field device (such as an RWIS station) reports its status on an hourly basis. The time to transmit its data including a "wake up" period is one minute.

Table A-2- Sleep Mode Power Calculation Example

	Peak Power	Sleep Power	Minutes per Day Peak	Minutes per Day Sleep	Total Peak	Total Sleep	Total Daily Power Consumption
Units	Watts	Watts	Minutes	Minutes	Watt/hrs/ day	Watt/hrs/ day	Watt/hrs/ day
Device One	0.3	0.07	24	1,416	0.12	1.65	1.77
Device Two	0.5	0.05	24	1,416	0.2	1.18	1.38

Here, although Device One has a lower peak power requirement by 40 percent, the lower consumption of Device Two's sleep mode make it a better choice as the overall consumption is lower by over 20 percent.

Performing this sort of power use analysis will be an important part of deploying reliable and cost-effective green energy systems.

Alternative Generation Technologies

Once the power needs for various types of ITS installations are understood, options for alternative or "green" generation methods can be assessed for suitability. Currently, photovoltaic solar and wind turbines are the most common method for generating off-grid power. In specific cases, a fuel generation system may also be used in place of a backup generator for cases where the primary system may not provide the required reliability.

Solar

Solar power systems have been used by WisDOT for a number of years and are based around well understood technology. Typically, a solar panel connects to a charge controller, which then regulates the charging of a battery and supplies power to the system load.

Proper sizing of the solar panels is vital to reliable operation and depends on both the load and on local environmental factors.

A property called "insolation" (**IN**coming**SOL**arRadi**ATION**), is used to calculate proper sizing for panels at a given location. Insolation gives a factor that takes into account day length, sun angle and atmospheric conditions to provide an average number of Sun-Hours on an average day at different times per year. In general the "Worst Winter Day" factor is used for planning purposes. Proper panel tilt based on latitude and assessment of shading conditions due to foliage at device sites must also be included in system design.

Wind

Wind power generation has become much more common in the last decade as a result of a favorable legislative and subsidy environment. Consequently, there has been an increase in the number of turbine system designs available for purchase. Some of the smaller systems (commonly called micro-turbines) may provide a suitable primary or supplemental generator for ITS installations.

Planning for wind power installation can be complex and should be completed prior to operational deployments of any systems. The major areas to be considered are described in the following sections.

Wind Resource

The average wind speed for a geographic location at a given altitude is called the "wind resource." The available power for a conventional wind turbine from the wind resource is described by the equation:

$$\textbf{Power} = 0.5 \times \textbf{Swept Area} \times \textbf{Air Density} \times \textbf{Velocity}^3$$

Given these factors, the size of the turbine (since Swept Area increases with the square of radius) and the wind speed have the most dramatic affects on the available power. A further factor called the Betz Limit also dictates that only 59.3 percent of the available power can be extracted by a wind turbine, regardless of design. When coupled with other mechanical and generation losses, usually only 15-30 percent of the available power can be converted for use.

Since velocity plays such a major role in system output, the turbine will most likely have to be placed on a structure that places it at least 30 feet above any tree within 500 feet. As elevation increases, generally average wind speed does as well, thus the highest practical elevation is desired. Usually this means that a 30-meter (100-foot) height is considered the minimum for a practical generation system.

Turbine Design

While the traditional "propeller-style" design for a wind turbine is the most common and generally offers the highest output, several other designs have been offered recently. Usually referred to as vertical axis wind turbines (VAWTs), these new designs use a vertical shaft with a variety of airfoil designs:

A **Darrieus** turbine uses thin, curved airfoils in an "eggbeater"-style layout. These designs are characterized by good efficiency, but high stress on the generator and bearing assemblies from the cyclical torque of the rotating airfoils. Due to the low start-up torque created by a Darrieus design, an external motor is needed to begin rotation.

Giromill turbines are similar to Darrieus designs, but the blades are vertical, parallel with the central shaft. These have lower startup torque, and thus do not need an external motor.

Savonius turbines are drag-based rather than airfoil based, similar to an anemometer wind-speed meter. These can be simple, high-reliability devices, but generally offer lower efficiency.

Environmental Restrictions

Due to the height needed for satisfactory output, the turbines will usually be above the top of the tree canopy in the area. This raises concerns for bird and bat populations that should be addressed prior to deployment.

Full environmental review of wind turbine installations is generally triggered when the power output capacity (typically referred to as "nameplate capacity") of a wind farm exceeds a certain value. Isolated ITS installations will not exceed a size needed for environmental review; however, every effort should be made to avoid environmental impacts.

The primary concern will be kills of birds and bats in the area of the turbine. The Migratory Bird Act, Bald Eagle protection Act and Endangered Species Act and any state-level regulation should be reviewed, and wind sites identified that may pose a risk of environmental harm.

Fuel Cell

Fuel cells use an electro-chemical reaction to produce electricity without moving parts. This results in a high-reliability power source with a good power to weight ratio. While Hydrogen-Oxygen fuel cells have been used in spacecraft for nearly 50 years, the difficulty of managing hydrogen in commercial environments has lead to the development of alternative chemistries.

The most common chemistry for commercial systems is methanol. WisDOT has already begun trial deployments of this type of fuel cell as a backup power source.

Because a fuel cell requires a supply of reactant to be stored on site, their use model is closer to a backup generator as opposed to a primary generator such as solar or wind. Given their high reliability, wide operating temperature range and good power density, fuel cells should be considered as a supplemental source of power to enhance reliability of green power installations.

Energy Storage

Solar and wind generation is inherently intermittent, so a robust storage system must be used to ensure continuous operation of ITS devices. There are several different methods of storing electrical energy that may be applicable to green power installations.

Battery Systems

Batteries store energy using electro-chemical reactions. These have been in commercial use since the approximately 1840, and are based on well understood technologies. Since they rely on chemical reactions, performance can vary considerably with temperature, and extremes of hot or cold can damage the cell. All batteries have a limited number of charge-discharge cycles (generally in the thousands) and as a result must be replaced on a three- to five-year cycle. Also, most batteries rely on toxic materials and must be handled and recycled appropriately.
Several chemistries are available for energy storage including:

Lead Acid

Lead Acid batteries are found in a wide variety of applications, from automotive to uninterruptable power supplies. A number of different types of batteries using this chemistry are available, with the type most applicable to ITS being the Absorbed Glass Mat (AGM) Sealed Lead Acid (SLA) battery.

AGM batteries use a fiberglass sheet to absorb the acid, resulting in a battery that can be installed in any orientation and will not leak, even when punctured. AGM batteries also have a wide operating range and are resistant to freezing. The lack of any exotic materials and compatibility with simple charging devices make them a very low cost option.

Power density is the chief drawback of the lead acid battery. High-capacity cells are bulk and can weigh hundreds of pounds when used in a multi-cell "pack" arrangement.

Lithium

To address the needs for smaller, higher-power density batteries for consumer electronic devices, alternative chemistries (Nickel-Cadmium (NiCad), Nickel-Metal-Hydride (NiMH), and Lithium) were developed. Of these, the various Lithium-based batteries have proven to be the most robust. With approximately three times the energy density of lead-acid, the various lithium chemistries (Iodine, chloride, iron) offer compact energy storage.

Lithium-based systems have several drawbacks, the primary one being cost for deployment. There are no readily available high-capacity battery packs; instead multiple smaller cells must be combined together. For example the electric powered Tesla Roadster requires 6,831 individual cells and with a dedicated liquid cooling system to prevent heat-related damage. This arrangement, in addition to being difficult to construct and maintain also requires sophisticated charging equipment that varied current based on feedback from the battery cells.

For this reason, rechargeable lithium batteries have not seen wide deployments in ITS power systems. However, the emergence of a market for electric vehicles has prompted some manufacturers to design and develop high capacity cells, and these may become available for commercial applications in the future. If appropriate charging systems are also available, Lithium batteries may become an attractive option in the future.

Capacitors

Capacitors store electric charge directly, rather than through a chemical reaction. This makes them relatively immune to temperature effects and gives them very long lifetimes.

Capacitors suffer from very low energy densities, typically one-tenth that of a lead-acid battery. As a result, very large capacitor banks are needed for robust storage systems. Capacitors also have the ability to discharge stored energy very rapidly. As a result, some care must be taken to avoid short-circuiting the terminals of capacitors as these can be lethal.

Several private firms are currently developing high-capacity capacitor designs that may have energy densities considerably higher than chemical battery systems. If these prove viable, the combination of high-density and relative immunity to environmental conditions would be very attractive for ITS deployments.

Mechanical (Flywheel)

Use of kinetic energy storage has been popular for some industrial applications. Using a lightweight, carbon-fiber flywheel spinning very rapidly (up to 140,000 rpm) in a vacuum chamber provides a system that can instantaneously deliver very large amounts of energy. Energy density of such a system approximates that of a lithium battery and does not require any specialized charging equipment. Being mechanical and typically using magnetic bearings, these systems are unaffected by temperature, making them attractive for roadside deployments.

At present, flywheel systems are not manufactured for small power demands such as a roadside vehicle detector or RWIS station. The large packaging of these systems makes them somewhat unattractive as green energy storage systems, but they may be applicable as backup systems for equipment huts and other larger installations.

Recommendations

Procurement Specifications

As WisDOT periodically updates its list of approved devices for ITS, consideration should be given to peak and average power consumption. This should include determinations of projected use patterns and the resulting effect on the use of sleep modes and other power saving features.

Solar and Wind Power Assessments

A series of test deployments of solar and wind power systems in representative locations throughout the state should be undertaken to gauge how differences in solar and wind resource availability affects power production. Test sites should be outfitted with data recorders to measure production and reserve capacity, as well as environmental conditions, such as temperature and cloud cover. A minimum of a one-year sample should be conducted to account for seasonal variation.

Wind Power Environmental Research

As noted above, the size of wind turbine installations envisioned for ITS applications is well below what would require an environmental review and permitting. However, to avoid potential issues it is recommended that a review of applicable regulations and environmental data, such as migratory bird flyways, be conducted and sites of potential conflict avoided.

Appendix B

Data Dictionary

ITS ELEMENTS

Field Name	Data Type	Description	Valid Values
OBJECTID	OID		
SHAPE	Geometry	Type of geographic feature	Point, Line, Polygon
ID	SmallInteger	Numeric ID, uniquie within feature class	Any integer
Longitude	Double	Latitude coordinate	0-180
Latitude	Double	Longitude coordinate	0-180
Corridor	SmallInteger	Identifier for relevant TOIP Corridor	1-14
ATR	SmallInteger	Yes/No value indicating if an ATR is present at the location	0(false), 1(true)
Traffic_Dt	SmallInteger	Yes/No value indicating if a Traffic Detector is present at the location	0(false), 1(true)
Signal_Imp	SmallInteger	Yes/No value indicating if Signal Improvements are present at the location	0(false), 1(true)
CCTV	SmallInteger	Yes/No value indicating if CCTV is present at the location	0(false), 1(true)
Ramp_Met	SmallInteger	Yes/No value indicating if Ramp Meters are present at the location	0(false), 1(true)
Ramp_CG	SmallInteger	Yes/No value indicating if a Ramp Closure Gate is present at the location	0(false), 1(true)
DMS	SmallInteger	Yes/No value indicating if a DMS is present at the location	0(false), 1(true)
PCMS	SmallInteger	Yes/No value indicating if PCMS is present at the location	0(false), 1(true)
Crash	SmallInteger	Yes/No value indicating if a Crash Investigation Site is present at the location	0(false), 1(true)
Law_Enf	SmallInteger	Yes/No value indicating if a Law Enforcement Pad is present at the location	0(false), 1(true)
Bandwidth	Double	Bandwidth needed for all devices at the site (in bits per second)	0-3000000
Priority	SmallInteger	Priority as assigned by the Project Management Team (on a corridor basis)	0 (priority not assigned), 1 (0-3 yr construction horizon), 2 (4-6 yr construction horizon), 3 (7-9 yr construction horizon), 4 (>10 yr construction horizon)
Enabled	SmallInteger	Flags point as valid for analysis (not used in CSL 1.0)	0(false), 1(true)
Near_Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near_Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Distance from point to nearest splice point or hut (in meters)	any positive value
Cost	Double	Cost of fiber installation from point to nearest splice point or hut (in dollars)	any positive value
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Method1_Cost	Double	Cost for the selected communications method (in dollars)	any positive value
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Method2_Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_Cost	Double	Cost for the selected communications method	any positive value
NEAR_FID	Integer	Numeric Identifier for the nearest Wisconsin State Patrol communications tower	1-100
NEAR_DIST	Double	Distance from point to nearest Wisconsin State Patrol communications tower (in meters)	any positive value
Notes	String	Miscellaneous notes	Any string (50 characters)

ATR

Field Name	Data Type	Description	Valid Values
Site Name	String	WisDOT name identifier for ATR sites	String
Site ID	Integer	Numeric ID, unique within feature class	Any integer
Dir	Integer	Unused WisDOT Attribute	
Vol	String	Unused WisDOT Attribute	
Spd	String	Unused WisDOT Attribute	
Cls	String	Unused WisDOT Attribute	
Lng	String	Unused WisDOT Attribute	
WIM	String	Unused WisDOT Attribute	
County	String	Unused WisDOT Attribute	
Location	String	Text description of ATR location	String
Lat	Double	Latitude coordinate	0-180
Long_	Double	Longitude coordinate	0-180
Shape	Geometry	Type of geographic feature	Point, Line, Polygon
Near Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Initial fiber distance computations (uncorrected base data, original assumptions; in meters)	any positive value
Cost	Double	Initial fiber installation cost computations (in dollars)	any positive value
Bandwidth	Double	Bandwidth needed for all devices at the site (in bits per second)	0-3000000
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Method1_Cost	Double	Cost for the selected communications method (in dollars)	any positive value
Enabled	SmallInteger	Flags point as valid for analysis (not used in CSL 1.0)	0(false), 1(true)
In TOIP	SmallInteger	Indicates is the ATR is also represented in the TOIP (ITS elements) data	0(false), 1(true)
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Method2_Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_Cost	Double	Cost for the selected communications method	any positive value
NEAR_FID	Integer	Numeric Identifier for the nearest Wisconsin State Patrol communications tower	1-100
NEAR_DIST	Double	Distance from point to nearest Wisconsin State Patrol communications tower (in meters)	any positive value
Priority	SmallInteger	Priority as assigned by the Project Management Team (on a corridor basis)	0 (priority not assigned), 1 (0-3 yr construction horizon), 2 (4-6 yr construction horizon), 3 (7-9 yr construction horizon), 4 (>10 yr construction horizon)
Notes	String	Miscellaneous notes	Any string (50 characters)

RWIS

Field Name	Data Type	Description	Valid Values
Shape	Geometry	Type of geographic feature	Point, Line, Polygon
FID_1	Integer		
DISTRICT	Integer	WisDOT assigned District Identifier (not used)	1-16
ESS_NUMBER	Double	WisDOT assigned station Identifier (not used)	
COUNTY	String	County in which station is located	String (Wisconsin Counties)
CITY	String	City in which station is located	String (Wisconsin Cities)
LOCATION	String	Text description of location (roadway intersection, etc.)	String
ID	Integer	Numeric ID, unique within feature class	Any integer
LATI	Double	Latitude coordinate	0-180
LOGI	Double	Longitude coordinate	0-180
Name	String	WisDOT assigned station name (not used)	String
HWY	String	Roadway name for RWIS station	String
NEAR_DIST	Double	Distance from point to nearest Wisconsin State Patrol communications tower (in meters)	any positive value
Near Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Initial fiber distance computations (uncorrected base data, original assumptions; in meters)	any positive value
Cost	Double	Initial fiber installation cost computations (in dollars)	any positive value
Bandwidth	Double	Bandwidth needed for all devices at the site (in bits per second)	0-3000000
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Method1_Cost	Double	Cost for the selected communications method (in dollars)	any positive value
Enabled	SmallInteger	Flags point as valid for analysis (not used in CSL 1.0)	0(false), 1(true)
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Method2_Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_Cost	Double	Cost for the selected communications method	any positive value
NEAR_FID	Integer	Numeric Identifier for the nearest Wisconsin State Patrol communications tower	1-100
Priority	SmallInteger	Priority as assigned by the Project Management Team (on a corridor basis)	0 (priority not assigned), 1 (0-3 yr construction horizon), 2 (4-6 yr construction horizon), 3 (7-9 yr construction horizon), 4 (>10 yr construction horizon)

PSAP

Field Name	Data Type	Description	Valid Values
Shape	Geometry	Type of geographic feature	Point, Line, Polygon
PSAP Name	String	Name used to refer to PSAP	Any String
PSAP County	String	Wisconsin County in which PSAP is located	Any String
PSAP Mail	String	Mailing Address to contact PSAP	Any String
Community	String		Any String
ST	String	State PSAP located in	Any String
ZIP_CODE	Double	PSAP zip code	Any String
ZIP_4	Double	PSAP extended zip code	Any String
Contact Name	String	Primary contact name	Any String
Contact Title	String	Primary contact title	Any String
Telephone	Double	PSAP telephone contact number	Any String
PSAP Service	String	Area served by PSAP	Any String
Last Update	Date	Date of last record update (unused)	Any String
Latitude	Double	Latitude coordinate	0-180
Longitude	Double	Longitude coordinate	0-180
Near Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Distance from point to nearest splice point or hut (in meters)	any positive value
Cost	Double	Cost of fiber installation from point to nearest splice point or hut (in dollars)	any positive value
Bandwidth	Double	Bandwidth needed for all devices at the site (in bits per second)	100000000
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Meth1_cost	Double	Cost for the selected communications method (in dollars)	any positive value
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Method2_Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_Cost	Double	Cost for the selected communications method	any positive value

SWEF

Field Name	Data Type	Description	Valid Values
Shape	Geometry	Type of geographic feature	Point
Id	Integer	Numeric ID, unique within feature class	Any integer
Near Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Distance from point to nearest splice point or hut (in meters)	any positive value
Cost	Double	Cost of fiber installation from point to nearest splice point or hut (in dollars)	any positive value
Bandwidth	Double	Bandwidth needed for all devices at the site (in bits per second)	
Enabled	SmallInteger	Flags point as valid for analysis (not used in CSL 1.0)	0(false), 1(true)
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Method2_Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_Cost	Double	Cost for the selected communications method	any positive value

DMV CENTERS

Field Name	Data Type	Description	Valid Values
Shape	Geometry	Type of geographic feature	Point
Center	String	DMV Service center name	Typically same as city
Address	String	Street address	Any valid street address
City	String	City	Any Wisconsin city name
State	String	State Name	WI
Zip	Double	Zip code for corresponding street address	Any valid Wisconsin zip code
County	String	County in which DMV center is located	Any valid Wisconsin County name
Latitude	Double	Latitude coordinate	0-180
Longitude	Double	Longitude coordinate	0-180
Near Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Distance from point to nearest splice point or hut (in meters)	any positive value
Cost	Double	Cost of fiber installation from point to nearest splice point or hut (in dollars)	any positive value
Bandwidth	Double	Bandwidth needed for all devices at the site (in bits per second)	10000000
Enabled	SmallInteger	Flags point as valid for analysis (not used in CSL 1.0)	0(false), 1(true)
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Methos2_Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_Cost	Double	Cost for the selected communications method	any positive value

HUT

Field Name	Data Type	Description	Valid Values
Site Name	String	Name to identify hut	Any String
Site ID	String	WisDOT assigned string identifier	HUT00XX to HUT00YY
Address County	String	Street Address and County	Any string representing a valid street address and county
Type_	String	Describes type of communication site	Hut, Hub, Office
HVAC	String	Indicates presence of climate control	X (true), <blank> false
Rodent	String		X (true), <blank> false
Weed	String		X (true), <blank> false
DC	String	Indicates presence of DC power supply	X (true), <blank> false
Batteries	String	Indicates presence of battery backups	Wisconsin owned batteries; State Patrol owned batteries; <blank>
Other Info	String	Miscellaneous	Blank,
Power Company	String	Name of utility supplying power	Any string representing a utility provider
Phone Onsite	String	Indicates dial-up telephone service available at site	X (true), <blank> false
PM Status	String	Power Management status	"DC Batteries", <blank>, "Power switched to the SP power plant"
Street	String	Street Address	Any valid street name and number
City	String	City	Wisconsin city names
State	String	State	Wi
Latitude	Double	Latitude coordinate	0-180
Longitude	Double	Longitude coordinate	0-180
F19	String	Unknown	Unknown
Shape	Geometry	Type of geographic feature	Point
Enabled	SmallInteger	Flags point as valid for analysis (not used in CSL 1.0)	0(false), 1(true)

UW CAMPUSES

Field Name	Data Type	Description	Valid Values
Campus	String	Text name of campus	Any string
Latitude	Double	Latitude coordinate	0-180
Longitude	Double	Longitude coordinate	0-180
Shape	Geometry	Type of geographic feature	Point, Line, Polygon
Near Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Distance from point to nearest splice point or hut (in meters)	any positive value
Cost	Double	Cost of fiber installation from point to nearest splice point or hut (in dollars)	any positive value
Bandwidth	Double	Bandwidth needed for all devices at the site (in bits per second)	100000000
Enabled	SmallInteger	Flags point as valid for analysis (not used in CSL 1.0)	0(false), 1(true)
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Method2_Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_Cost	Double	Cost for the selected communications method	any positive value

HAR

Field Name	Data Type	Description	Valid Values
Shape	Geometry	Type of geographic feature	Point
Id	Integer	Unique numeric identifier	0 (not used)
Near Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Distance from point to nearest splice point or hut (in meters)	any positive value
Cost	Double	Cost of fiber installation from point to nearest splice point or hut (in dollars)	any positive value
Bandwidth	Double	Aggregate bandwidth needed for all devices at the site	9600
Enabled	SmallInteger	Flags point as valid for analysis (not used in CSL 1.0)	0(false), 1(true)
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Method1_ Cost	Double	Cost for the selected communications method (in dollars)	any positive value
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Method2_ Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_ Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_ Cost	Double	Cost for the selected communications method	any positive value

REST AREAS

Field Name	Data Type	Description	Valid Values
Facility No_	Double	WisDOT assigned facility identification number	9-106
Location	String	Text description of location	Any string
Latitude	Double	Latitude coordinate	Not Used
Longitude	Double	Longitude coordinate	Not Used
Shape	Geometry	Type of geographic feature	Point
Near Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Distance from point to nearest splice point or hut (in meters)	any positive value
Cost	Double	Cost of fiber installation from point to nearest splice point or hut (in dollars)	any positive value
Bandwidth	Double	Bandwidth needed for all devices at the site	100000000
Enabled	SmallInteger	Flags point as valid for analysis (not used in CSL 1.0)	0(false), 1(true)
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Method2_Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_Cost	Double	Cost for the selected communications method	any positive value

SIGNALS

Field Name	Data Type	Description	Valid Values
Shape	Geometry	Type of geographic feature	Point
Id	Integer	Assigned numeric identifier	0-1000
signal_num	String	WisDOT assigned signal cabinet ID	S004-S1332, SS 0097L1-SS 0150L3, T1008, T1019, T323, T324, U1305, U1315

TRAUMA CENTERS

Field Name	Data Type	Description	Valid Values
Name	String	Hospital Name	Any String
Latitude	String	Latitude coordinate	numeric string values for degrees, mintes secongs
Longitude	String	Longitude coordinate	numeric string values for degrees, mintes secongs
LatDD	Double	Latitude coordinate	0-180 (digital degrees)
LonDD	Double	Longitude coordinate	0-180 (digital degrees)
Shape	Geometry	Type of geographic feature	Point, Line, Polygon
Near Splice	SmallInteger	Numeric identifier of the nearest valid fiber optic splicing location	0-999 (0-799 for existing vaults, 800-899 for fiber runs where vaults could be added, 999 for vaults along projected fiber runs)
Near Hut	SmallInteger	Numeric identifier of the nearest valid fiber optic communications hut	0-999
Distance	Double	Distance from point to nearest splice point or hut (in meters)	any positive value
Cost	Double	Cost of fiber installation from point to nearest splice point or hut (in dollars)	any positive value
Bandwidth	Double	Bandwidth needed for all devices at the site	100000000
Method1	SmallInteger	Numeric identifier for selected communications method at point (uncorrected base data, original assumptions)	1-8
Meth1_cost	Double	Cost for the selected communications method (in dollars)	any positive value
Method2	SmallInteger	Numeric identifier for selected communications method at point (corrected base data; all fiber optic baseline costs)	1-8
Method2_Cost	Double	Cost for the selected communications method	any positive value
Method3	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, original assumptions)	1-8
Method3_Cost	Double	Cost for the selected communications method	any positive value
Method4	SmallInteger	Numeric identifier for selected communications method at point (corrected base data, revised assumptions)	1-8
Method4_Cost	Double	Cost for the selected communications method	any positive value

TOIP CORRIDORS

Field Name	Data Type	Description	Valid Values
SHAPE	Geometry	Type of geographic feature	Polyline
Corridor	String	Name of TOIP priority corridor	Badger State, Capitol, Chippewa Valley, Cornish Heritage, Coulee Country, Fox Valley, Glacial Plains, Hiawatha, Peace Memorial, South Central Connection, Southern Tier, Title town, Wild Goose, Wisconsin River
SHAPE Length	Double	Length of corridor (in meters)	Any positive value

WSP COMMTOWERS

Field Name	Data Type	Description	Valid Values
Shape	Geometry		Type of geographic feature
Id	Integer	Unique numeric identifier	1-99

FIBER DESIGN 3

Field Name	Data Type	Description	Valid Values
Facility ID	SmallInteger	Numeric identifier	
Facility Ra	SmallInteger	Facility rank assigned at time of network analysis and routing	
Name	String	Internal software to-from naming parameter	
Incident Curb	SmallInteger	Incident curb approach (internal parameter assigned by software)	
Facility Curb	SmallInteger	Incident curb approach (internal parameter assigned by software)	
Incident ID	SmallInteger	Order in which Network Analyst evaluated routes	
Total Distance	Double	Distance from incident to facility of original route	
Shape Length	Double	Length of fiber segment (in meters)	
Continuity	SmallInteger	Indicates if a fiber segment is to provide a device connection or network continuity	0(false), 1 (true)

HIGHWAY FIBER NET

Field Name	Data Type	Description	Valid Values
RECTYPE	FHWA Network Attributes (unused)	-	-
VERSION	FHWA Network Attributes (unused)	-	-
RECID	FHWA Network Attributes (unused)	-	-
ORIGID	FHWA Network Attributes (unused)	-	-
STFIPS	FHWA Network Attributes (unused)	-	-
CTFIPS	FHWA Network Attributes (unused)	-	-
SOURCE	FHWA Network Attributes (unused)	-	-
LGURB	FHWA Network Attributes (unused)	-	-
SMURB	FHWA Network Attributes (unused)	-	-
SIGN1	FHWA Network Attributes (unused)	-	-
SIGNT1	FHWA Network Attributes (unused)	-	-
SIGNN1	FHWA Network Attributes (unused)	-	-
SIGNQ1	FHWA Network Attributes (unused)	-	-
SIGN2	FHWA Network Attributes (unused)	-	-
SIGNT2	FHWA Network Attributes (unused)	-	-
SIGNN2	FHWA Network Attributes (unused)	-	-
SIGNQ2	FHWA Network Attributes (unused)	-	-
SIGN3	FHWA Network Attributes (unused)	-	-
SIGNT3	FHWA Network Attributes (unused)	-	-

SIGNN3	FHWA Network Attributes (unused)	-	-
SIGNQ3	FHWA Network Attributes (unused)	-	-
LNAME	FHWA Network Attributes (unused)	-	-
MILES	FHWA Network Attributes (unused)	-	-
KM	FHWA Network Attributes (unused)	-	-
FCLASS	FHWA Network Attributes (unused)	-	-
RUCODE	FHWA Network Attributes (unused)	-	-
STATUS	FHWA Network Attributes (unused)	-	-
NHS	FHWA Network Attributes (unused)	-	-
STRAHNET	FHWA Network Attributes (unused)	-	-
FAC_ID	FHWA Network Attributes (unused)	-	-
CONN_ID	FHWA Network Attributes (unused)	-	-
CONN_DES	FHWA Network Attributes (unused)	-	-
CONN_MILES	FHWA Network Attributes (unused)	-	-
LRSKEY	FHWA Network Attributes (unused)	-	-
LRSSEQ	FHWA Network Attributes (unused)	-	-
BEGMP	FHWA Network Attributes (unused)	-	-
ENDMP	FHWA Network Attributes (unused)	-	-
AADT	FHWA Network Attributes (unused)	-	-
ThruLanes	FHWA Network Attributes (unused)	-	-

OwnerShip	FHWA Network Attributes (unused)	-	-
Enabled	FHWA Network Attributes (unused)	-	-
Shape_Length	Double	Length of fiber segment	Any positive value
Fiber	SmallInteger	Status of fiber facility	1 (existing), 2 (planned), <null>
Owner	SmallInteger	Owning entity for fiber facility	<Null>, 1 (WisDOT), 2 (AT&T), 3 (Qwest), 4 (UW), 5 (CINC), 6 (Paetec), 7 (Brown County), 8 (Green Bay), 9 (signal), 10 (Spiralight), 11 (Waukesha), 12 (MERIT)
County	SmallInteger	Number of fiber strands available to WisDOT	0, 2, 4, 6, 8, 10, 12, 24, 36, 72, 999 (planned/unknown)
Priority	SmallInteger	Corresponding corridor Priority (if relevant)	1 (0-3 yr), 2 (4-6 yr), 3 (7-9 yr), 4 (>10 yr)

FIBER SPLICE

Field Name	Data Type	Description	Valid Values
SHAPE	Geometry	Type of geographic feature	Point, Line, Polygon
ID	SmallInteger	Unique numeric identifier	1-500
Longitude	Double	Unused Coordinate	-
Latitude	Double	Unused Coordinate	-
Owner	String	Splice vault owning entity	AT&T, City of Madison, McLeod, Paetec, Qwest, WisDOT
Flagged	String	Unused	Yes, No
Hut	String		Blank, Eau Claire, Green Bay, Madison, Milwaukee, Sheboygan, Thorp, Wausau
Enabled	SmallInteger	Valid Network Analyst feature flag	0 (False), 1 (True)
Corridor	String	Identifies if the vault lies on the I-94 corridor (determines if vault is a valid splice point)	Blank, I-94
Access	String	Identifies if the vault is accessible for use by WisDOT	Yes, No