Pennsylvania Traffic Signal Systems: A Review of Policies and Practices (2004)

STATE TRANSPORTATION ADVISORY COMMITTEE

COMMONWEALTH OF PENNSYLVANIA

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FINAL REPORT
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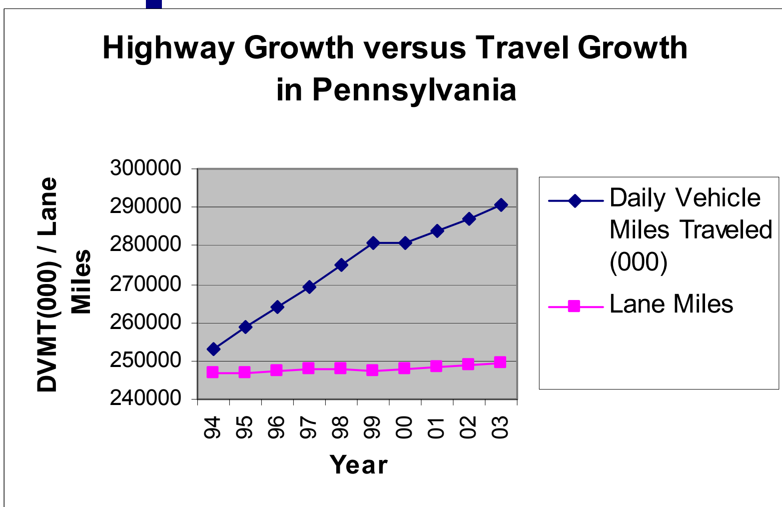
EXECUTIVE BRIEF: ISSUES AND BROAD PERSPECTIVE

This Transportation Advisory Committee (TAC) examined Pennsylvania's Traffic Signal Systems and the policies and practices associated with their management and operation. In particular, traffic signal systems were considered in the context of their role in congestion relief.



Traffic signals are part of the paradigm shift of how we think about transportation. **Historically, the transportation industry has focused on building additional capacity to address congestion.** As a result, traffic signal practices were centered on design, construction and maintenance. **More recently, the focus has shifted to managing and optimizing capacity as well as reducing demand** by promoting alternative modes of travel and land use strategies. **Transportation operations are the means and the methods to better manage existing capacity.** Transportation operations include elements, such as intelligent transportation systems (ITS), incident management, highway and transit operations, as well as traffic signal system operations. Traffic signal operations include:

- Operational oversight to ensure the signal is safely and efficiently meeting traffic demands at that intersection
- Safely and efficiently meeting traffic demands on a corridor and regional level via interconnected and coordinated traffic signal systems
- Consideration of non-recurring events such as incident management, homeland security, and special events
- Safely and efficiently accommodating pedestrians and other transportation modes
- Safely and efficiently processing emergency vehicles.

Improved transportation operations represent one especially important strategy given the relatively low cost compared to the benefits of increasing system capacity. While each strategy (new capacity and operations) is important and has its rightful place, efforts to improve operations should not be overlooked, particularly in this fiscally constrained environment.

The future of transportation operation is best illustrated by the concept of an integrated arterial/freeway corridor, and the transportation systems utilized. In an integrated arterial/freeway corridor, arterial travel times, speeds, and conditions may be shared with freeway management to adjust Changeable Message Signs (CMS), Highway Advisory Radio (HAR), and freeway ramp meters. Conversely, freeway travel times, speeds, and conditions may be shared with arterial management and used to optimize traffic signal timings and inform arterial travelers. Such integration may also use incident response timing plans to respond to traffic diverted from the freeway to the arterial.

BACKGROUND

Currently, there are more than 13,600 traffic signals in Pennsylvania that are owned and maintained by 1,192 (47%) of Pennsylvania's 2,655 municipalities. Of the municipalities owning traffic signals, 80 percent have 10 or less signals, 64 percent have five or less signals, and 25 percent have one signal. Many of these municipalities have neither the technical expertise nor the resources to maintain and operate their traffic signals. There is minimal operational oversight at the state level after initial installation as PennDOT's authority is limited. As a result, many traffic signals are viewed on a "microscopic" jurisdictional level. Regional implications and opportunities as to how to best manage and operate the signal systems may not be fully realized or even considered.

CORE THEMES

Pennsylvania signal systems are a $1 billion asset that are not managed and operated to their fullest. That is important context for evaluating the issues associated with the policies and practices of traffic signal systems. Key themes identified in this study include:

- Signal systems are an asset that should be better managed as such so that systems can be better planned, maintained and operated to reduce congestion
- Signal systems need be both maintained and operated. Operations include the development of appropriate operations parameters/standards, addressing special needs such as events, homeland security and incidents, and providing oversight to ensure systems are functioning properly and efficiently.
- Signal systems should be a shared responsibility that requires the multi-jurisdictional cooperation and input of local municipalities, PennDOT, planning organizations and other stakeholders.
- Signal systems cannot only be considered on a microscopic, jurisdictional level, but should also be considered on a corridor and regional level.
- A number of policy and procedures such as signal permitting need to be evaluated to address appropriate roles and responsibilities; the importance of signal systems and the highway occupancy permit process with regard to signal systems.
- Technology is rapidly changing, requiring continual training and education to ensure that signal systems can be designed, maintained and operated efficiently.
- Procurement policies can discourage technology implementation. Creative approaches are needed to both encourage continued research, and more importantly, to test and disseminate that research in an applied way throughout the Commonwealth.

These themes are addressed in the study through twelve core recommendations along with nearly 30 secondary recommendations.

FINANCIAL CONSIDERATIONS

Texas Transportation Institute and the Federal Highway Administration (FHWA) figures indicate that five percent of the nation's $72 billion in delay costs and wasted fuels can be attributed to the congestion associated with traffic signals. This equates to approximately $12,000 in delay and fuel costs per traffic signal annually. **In Pennsylvania, total delay and fuel costs at signalized intersections is estimated to be $120 million to $160 million annually.**

According to the Institute of Transportation Engineers (ITE), **the average annual maintenance cost per signal is $2,760.**ITE also estimates signal maintenance is under funded nationally by 20 percent. In Pennsylvania, the estimated average amount spent on maintenance (of those surveyed) is around $1,950 annually. These dollar values reflect basic maintenance which includes items such as changing light bulbs and utility service, but do not include operational costs**.** Based on ITE's figures, it is estimated that **annual operational costs for effectively managed systems could range from $500 to $3,000 per year per signal** depending on the complexity and level of oversight. Study stakeholders indicate maintenance and operations does not get sufficient priority to other priorities and financial constraints.

Presently, there are three primary funding sources for traffic signal systems. However, most funding is for design and installation with less emphasis on maintenance and operations.

- State Liquid Fuels funds can be spent on the acquisition, maintenance, repair, and operation of traffic signs and signals. Most stakeholders, however, noted that the funds are used for utility service and basic maintenance. As a result, funds are not often available to improve signal operations.
- Traffic signals may also be funded through the Transportation Improvement Program (TIP). The TIP sometimes funds the design and construction of new signal systems, but has limited use in addressing operational requirements of signal systems. The TAC believes PennDOT and planning organizations should give more systematic attention to traffic signals in the regional programming process – where TIP development occurs.
- PennDOT regulates access to state roads through the issuance of Highway Occupancy Permits (HOP). If traffic impacts require new or upgraded traffic signals, PennDOT will typically require the developer to pay for installation of such signals. The developer, however, is seldom responsible for the cost of maintenance or operations. This situation is exacerbated in tax-free areas when a developer may not have to pay taxes, which could be used for signal maintenance and operations.

Although much can be accomplished without increased funding, a new funding source would allow the TAC recommendations to be implemented more quickly and to a far greater level as well as provide additional support for operations and maintenance. Further, the TAC recommendations reflect an overall integrated strategy: one that could be better leveraged with additional resources. Funding for improved traffic signal systems should be considered as part of any future state transportation funding increases. This will serve to emphasize the importance of efficient operations. New funding can also leverage many other favorable results including a performance-based approach for receiving funds based on updated standards.

BENEFITS

By improving the coordination and performance of our traffic signal systems through better maintenance, operations and management practices, the following benefits can be realized:

- Reduced congestion on many of our major arterials
- Optimize the capacity of our existing infrastructure
- Improved air quality and decreased fuel consumption
- Reduced congestion-related crashes
- Improved response of emergency vehicles/services
- Promote more efficient transit system(i.e., transit signal preemption which allows transit vehicles to control signals)
- Respond to non-recurring special needs such as incident management, homeland security and special events
- Improved regional cooperation on signal system management and related transportation issues
- Improved utilization of existing and future resources by better planning, deploying and managing signal systems
- Stimulate economic development by making our roadways and our cities more accessible.

Important Note: TAC's recommendations reflect a systematic approach. Although some of the recommendations could be pursued individually, most recommendations are inter-related and the maximum benefit would be achieved through a more comprehensive approach. TAC believes increased funding for traffic signals is not only justified on a benefit-to-cost basis, but fits with the Secretary's direction of improving the efficiency and effectiveness of existing facilities.

EXECUTIVE SUMMARY

- **Traffic signal** – a power-operated traffic control device by which traffic is warned or directed to take some specific action
- **Signal installation** – all of the equipment or material involved in the control of traffic at one intersection by a traffic signal
- **Signal system** – two or more signal installations operating in coordination

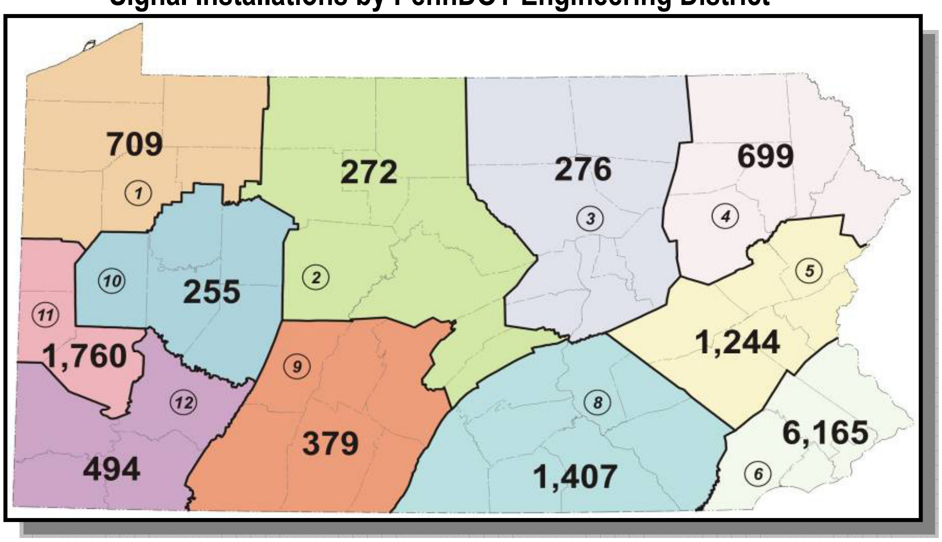
INTRODUCTION

This Transportation Advisory Committee (TAC) examined Pennsylvania's Traffic Signal Systems and the policies and practices associated with their management and operation. In particular, traffic signal systems were considered in the context of their role in congestion relief.

Even with the primary focus on congestion, issues and recommendations are identified that directly or indirectly have implications for safety, intelligent transportation systems (ITS), traffic control centers, and other facets of the total transportation system that interface with traffic signals.

Currently, there are more than 13,600 traffic signals in Pennsylvania that are owned and maintained by 1,192 (47%) of Pennsylvania's 2,655 municipalities. Of the municipalities owning traffic signals, 80 percent have 10 or less signals, 64 percent have five or less signals, and 25 percent have one signal. Many of these municipalities have neither the technical expertise nor the resources to maintain and operate their traffic signals. There is minimal operational oversight at the state level after initial installation as PennDOT's authority is limited. As a result, many traffic signals are viewed on a "microscopic" jurisdictional level. Regional implications and opportunities as to how to best manage and operate the signal systems may not be realized or even considered.

Signal Installations by PennDOT Engineering District



Traffic signals are representative of the paradigm shift of how we think about transportation. **Historically, the transportation industry has focused on building additional capacity to**

address congestion. As a result, traffic signal practices have focused on design, construction and maintenance. **More recently, the focus has shifted to managing and optimizing capacity as well as reducing demand** by promoting alternative modes of travel and land use strategies. **Transportation operations are the means and the methods to better manage existing capacity.** Transportation operations include elements, such as incident management, highway and transit operations, as well as traffic signal system operations.

TAC Study Objectives

The TAC set three objectives to guide this study:

- Produce an evaluation of relevant issues associated with the policies and practices of traffic signal systems throughout the Commonwealth.
- Identify alternatives to reduce congestion.
- Make feasible recommendations for ways traffic signal systems might be better planned, deployed, and managed to improve safety and congestion management.

While the following text is longer than a typical vision statement, it is encompassing of the broad – based approach required:

A Recommended Vision

The vision of **Pennsylvania's 21st Century traffic signal systems** includes a ***holistic approach*** to the operations and maintenance of signal systems driven by renewed ***policies and practices*** that identify ***institutional responsibilities and accountability***. In addition to being adequately maintained, the systems will be ***efficiently operated*** so that they properly respond to traffic demands including incidents, homeland security needs and special events. The systems will be planned, designed, constructed, maintained and operated by an ***effectively trained*** interdisciplinary staff and utilize a level of ***technology*** appropriate for the signal systems and the staff supporting them. ***Education*** of the importance and operations of signal systems to stakeholders and the public would elevate awareness.

Methodology

This TAC report was developed using a three phase process:

Phase I – General Assessment – This phase included stakeholder involvement and research for the purpose of issue identification and to focus Phase II on issues of greatest importance. A statewide stakeholder workshop was held in Camp Hill on July 1, 2004. Stakeholder participants identified many issues related to Pennsylvania's Traffic Signal Systems.

Once the initial issues were identified through the workshop, in-depth research occurred drawing from more than 80 publications/sources. Research results were used to determine over 50 best and innovative practices.

July 1st Workshop Core Themes

- Funding
- Holistic approach to signal systems
- Training
- Operational monitoring and audits
- PennDOT authority
- Embrace technology
- Access management and land use
- Maintenance & operations guidelines
- Ownership

Phase II – Issues Evaluation – This phase provided an in-depth evaluation of issues identified during the first phase. The results from this phase were used to develop draft findings and recommendations.

Phase III - Final Report Development and Presentation – The third and final phase of the study process entailed the development of a draft final report which took into consideration all information collected during the first two study phases. A preliminary draft was presented to the TAC Task Force for review. A revised draft final report was presented to the full TAC in December 2004 and a final version to the State Transportation Commission in January 2005.

RESEARCH RESULTS

The study included a significant research and benchmarking effort. This research along with input from Task Force Members, PennDOT Central Office, other states and PennDOT Districts was used to move toward the study outcomes. Key research results are organized around the following seven major themes:

Holistic Approach

- ❑ The need to think at a larger scale, be it corridor, county, region, district, or statewide, is imperative to getting the maximum benefit of traffic signal systems that cross municipal boundaries. This presently does not routinely occur, but represents the most broad and strategic opportunity for a paradigm shift toward comprehensive traffic signal system management.

Planning / Policy Driven

- ❑ A representative slate of lower-cost traffic signal projects with higher benefit-to-cost ratios fail to be included on the TIP when compared to other higher-profile, higher-cost construction projects.
- ❑ Traffic signal technology continues to evolve as part of the overall technology revolution, yet Pennsylvania has many antiquated signal systems.
- ❑ There are several innovative ways to overcome jurisdictional problems. These include formal and informal agreements between municipalities for corridor and region wide signalization projects.

Institutional Responsibilities / Accountability

- Institutional structures and disconnects can limit the ability of traffic signal systems to adapt to changing policies, technologies, and corridors/regional approaches. One way to overcome this obstacle is thru an interjurisdictional, oversight committee, as in Arizona which defines and enforces oversight policies.

Efficient Operations

- Efficient operations are essential to getting the most out of installed traffic signal technology and maximizing lane capacity. There are varied examples of daily oversight and fine tuning of traffic signals to ensure maximum performance.
  - A study entitled *ITS Benefits: The Case of Traffic Signal Systems* (A. Skabardonis) concluded that optimizing traffic signal timing plans, properly coordinating signal systems and implementing adaptive signal systems at some locations resulted in a 24.9 percent reduction in delay in the 76 corridors studied.
  - An Institute of Transportation Engineers article *entitled The Benefits of Retiming Traffic Signals* (April 2004) presented eight examples where retiming reduced delay by eight to 40 percent.
  - An ITE publication entitled *Traffic Control System Operations: Installation, Management and Maintenance* helped quantify the efficiency benefits. Each dollar spent optimizing signal timings could yield as high as a 20 gallon fuel saving. In York County, Virginia, traffic signal improvements along a 1.5 mile corridor decreased fuel consumption by 11 gallons per 1,000 vehicles in the corridor.
  - PennDOT's Traffic Signal Enhancement Initiative and Congested Corridor Improvement Program have produced delay savings of 15 to 20 percent for the 35 corridors studied with a benefit to cost ranging from 7.2 to 15.9.

Effective Training / Education

- Education and training for public sector officials and the public at large is a key to increasing support for traffic signal improvements and ensuring the maximum efficiency of existing systems.
- When linked with ITS capabilities, there are many options to engage the public via websites and cable television to educate and inform the public of traffic conditions and issues.
- Training for traffic engineers and public officials can also improve efficiency, whether it is an extensive course over several days or a more localized course covering a broader range of issues. Discussions with PennDOT District Traffic Engineers revealed an interest in development of standardized education and training courses or training signal employees.

Effective Use of Technology

- Innovations in traffic signal technology are happening every day and it can be hard to keep up. This makes the ongoing evaluation of traffic signal technology through pilot programs a key strategy, and the reporting and sharing of the results an essential follow-up.

Improved Funding Strategies

- ❑ Several studies on signal funding include innovative strategies.
- ❑ One fundamental step to improving funding for traffic signals is to educate the public as to the cost of maintaining these systems, the benefits of doing so, and the importance of well maintained traffic signals.
- ❑ There are many different approaches to how funding is allocated as well.
  - Denver Regional Council of Governments (DRCOG) has led the way in regional funding for traffic signals at the MPO/RPO level with their Regional Traffic Signal Improvement Program (RTSIP).
  - In the Las Vegas Area Computer Traffic System (LVACTS), cost sharing is determined by formula. The basic rate structure is determined initially after a division of fifty (50) percent from the City of Las Vegas and proportionately from the other member agencies. Agreement formulas include functions such as number of signals under LVACTS control.
  - TranStar (Texas) Executive Committee is comprised of a representative from TxDOT, the Metropolitan Transit Authority of Harris County, Harris County, and the City of Houston. Each agency contributes to the annual operating budget of the TranStar Traffic Control Center on a prorated basis relative to their occupancy and utilization of building components.
- ❑ State policy makers should consider designating some percentage of future funding increases to operations and traffic signal systems as a relatively low cost way of enhancing capacity and safety.

PENNSYLVANIA BEST PRACTICES

A study of this nature often focuses problems in order to identify potential improvements. It should be noted, however, that there are several innovative and best practices taking place within the Commonwealth.

- ❑ Several PennDOT districts are utilizing some form of asset management. In some cases, it involves a simple spreadsheet while other districts have implemented a geographic information system (GIS) application.
- ❑ Most PennDOT districts work informally with municipalities to identify and address operational issues.
- ❑ Most PennDOT districts have tried to provide specialized training utilizing national training programs such as the Center for Intelligent Transportation Engineering (CITE), Synchro training programs, Highway Capacity Software training programs, and the Northwestern University Traffic Signal Workshops.

- PennDOT's Traffic Resources Education and Computing Support (TRECS) group meets quarterly to assess software and hardware needs including training as well as to discuss publication needs.
- There are a few cross-jurisdictional signal systems currently deployed in Pennsylvania.
- Both the Traffic Signal Enhancement Initiative (TSEI) and the Congested Corridor Improvement Program (CCIP) are valuable tools in congestion reduction. The goal of the TSEI is to reduce travel times and delay on specified signalized corridors. The TSEI focuses primarily on signal issues such as timing, operations, maintenance, and technology. The objective of the CCIP is to reduce delay by 20 percent on selected corridors. CCIP improvements are directed at activities such as roadway geometry, signal operations, access management, multimodal initiatives, intelligent transportation systems (ITS), traffic regulation techniques, transportation demand management (TDM) measures, and planning and zoning practices that are appropriate for a particular transportation corridor.

RECOMMENDATIONS

The TAC Task Force members identified approximately 50 potential solutions or recommendations. Twelve of these potential solutions were identified as Tier I solutions – those having the greatest potential in problem solving.

Tier I Solutions
Develop an Asset Management System Asset management is a strategic approach to managing transportation infrastructure. It includes a set of principles and practices for building, preserving and operating facilities more cost-effectively and with improved performance, delivering the best value for public tax dollar spent, and enhancing the credibility and accountability of the transportation agency. The vision for a PA traffic signal asset management system would be a multi-agency database tool that could be used to perform a variety of functions and querying capabilities. PennDOT, for example, has robust systems that include conditions for state and local bridges, but not for traffic signals—both are important assets that using today's database technology can be better managed. In the long-term, all asset management system may be unified so that all disciplines have access to needed information. Ultimately, an asset management system would give stakeholders a tool to strategically manage a $1 billion asset and their maintenance and operational needs estimated at $60 to $90 million per year.
Pursue Tiered Operations and Maintenance on Critical Corridors Operations on critical corridors are a primary concern. Under current conditions, many of the signal systems along a specific corridor are operated individually by a local authority and sometimes without the broader consideration of the entire corridor. A holistic approach would be to pursue tiered operations and maintenance along critical corridors across jurisdictional boundaries. Tiered operations may include municipal maintenance with some PennDOT operational oversight and responsibility (during incidents/ events, peak hours, etc.). This is consistent with the new Mobility Strategic Focus Area Executive Goal to "effectively and efficiently operate the transportation system." Ensuring that critical transportation corridors function to the best of their ability should be a concern of all stakeholders. As such, a need exists to facilitate better communications between the respective organizations and work together to determine solutions that promote traffic signal coordination along critical corridors, which includes the identification these critical corridors. Critical corridors should include the development of a Corridor Consortium that meets on a regular (but not time intensive) basis to discuss issues that relate to efficient transportation along each corridor. The MPO/RPO can be one forum for facilitating this activity.

Tier I Solutions

Pursue Tiered Operations and Maintenance for most Signals

A tiered, interjurisdictional effort along critical corridors may be the best approach in the short-term, long-term solutions may consider tiered operations and maintenance of all signal systems.

Regional Signal Committees would work with planning organizations as well as PennDOT and other transportation partners in the regional oversight and prioritization of signal system enhancements as well as promoting the importance of addressing signal systems. Regional Signal Committees should be coordinated by planning organizations and may be similar to ITS subcommittees that exist within many planning organizations. This would be a natural extension of the regional ITS architectures that are currently being developed.

Promote a "Holistic" Approach to Signal Management

The development of an asset management system and a tiered approach to operations and maintenance establishes a conduit for PennDOT and planning organizations to develop a Regional Traffic Signal Improvement Program (RTSIP).

To establish a holistic approach to signal management several elements need to occur:

- ❑ Stakeholders need a tool to assess regional traffic signal needs (asset management tool) and need to prioritize signal enhancement projects (RTSIP).
- ❑ Operations needs to be considered in the funding process through the involvement of ITS Coordinating Councils and Regional Signal Committees.
- ❑ Traffic signal enhancements and operation need to be consistent and supported by the District's Transportation System Operations Plan (TSOP).
- ❑ Projects/ investments need to demonstrate quantifiable benefits.

Furthermore, this solution is consistent with PennDOT's Transportation Systems Operations Plan. The Transportation System Operations Plan (TSOP) defines: Why, What, and How with regard to managing capacity. "Traffic Signal Operations" is one of four critical elements of the TSOP. As the TSOP continues to be developed, it will be presented to District Executives and to planning partners. This will be a significant opportunity to promote signal systems management at a holistic level.

Expand Traffic Signal Enhancement Initiative (TSEI) and Congested Corridor Improvement Program (CCIP)

Both PennDOT's Traffic Signal Enhancement Initiative and Congested Corridor Improvement Program are valuable tools in congestion reduction.

The current funding levels of TSEI and CCIP are $1.2 million per year. These funding levels only begin to address the funding needs for signal improvements. Nevertheless, to make both programs more successful, each program should be expanded at a minimum rate of 10 percent per year up to 150-200 percent of existing funding levels. Additionally, both processes should be refined, if needed, in order to make implementation of improvements as timely as possible. Program results should focus on improvements such as timing plans that can be implemented without additional study.

Review and Update the Traffic Signal Permit Process

The review and update of the existing traffic signal permit process offers a mechanism for shared accountability, but also offers opportunities to more efficiently operate and manage signal systems by tracking critical characteristics and attributes. The review and update should be organized by two phases: Technical and Legal.

Tier I Solutions
Establish Operational Audits Program Several stakeholders cited that critical signal systems are not evaluated frequently enough due to data collection and analysis costs. Critical systems are typically those on major arterials or state routes. Ideally, critical systems should be extensively evaluated every three to five years. An efficient and cost-effective procedure should be considered that periodically assess critical systems in order to improve operations. Several districts perform informal operational assessments of critical corridors on a periodic basis or when issues arise; however, no formal process and protocol exists for performing these assessments. Guidelines and protocols for performing operational audits should be established so that key stakeholders are involved/ aware of the process (including resource needs) and as such can promote needed improvements. This could be piloted in one PennDOT District
Complete Updates and Revisions to PennDOT Traffic Signal Publications PennDOT publications and guidelines provide a vital tool for both PennDOT and local authorities in designing, constructing, maintaining and operating signal systems. Signal systems involve a variety of disciplines and evolving technologies. PennDOT is currently updating several traffic signal publications. These publications should continue to be updated. Where deficiencies in PennDOT publications exist, national publications should be identified or additional materials should be developed. The Internet provides an important resource for keeping these publications current and for disseminating changes on a broad scale.
Allocate a Portion of Any New Funding Increase to Signals The TAC believes that a dedicated traffic signal systems funding source is not only needed, but justified as traffic signals often become a low priority given competing needs by local government planning partners, and the Department in broader planning and programming activities. These funds could be applied to the operations as well as maintenance of the systems. TAC recommends that some portion of any new funding source (i.e., an increase in the gasoline tax) be allocated for operations including signal systems operations and maintenance. The operations and maintenance of Intelligent Transportation Systems should also be considered, but was not the focus of this study.
Provide Incentives for Operational Enhancements Presently, there are not direct incentives for operational enhancements; therefore, municipal practices focus on maintenance keeping the signals operating in a red/yellow/green mode and to avoid liability issues, not necessarily on operational efficiency. Operational enhancements could significantly improve safety and mobility at a low cost. If additional funding is secured, financial incentives should be extended to municipalities for implementing operational enhancements. Financial incentives should be used to encourage municipalities to invest in proactively monitoring, operating, maintaining and managing their traffic signal systems. Often, these enhancements can be implemented at a relatively low cost. The incentive should cover a percentage of the evaluation, design and implementation of the enhancement provided that the benefits can be demonstrated/documented. The exact percentage of incentive should be further evaluated to determine an appropriate level that encourage municipal participation, but does not result in unlimited requests.
Encourage Regional Maintenance Contracts with Operational Incentives Shared maintenance across jurisdictional boundaries provides an opportunity to decrease signal maintenance contract costs and also provides an opportunity to improve operations through better coordination and communication as well as through operational incentives to maintenance contractors. Shared maintenance contracts provide an opportunity to share resources thus reducing costs. Shared maintenance practices are most beneficial in rural areas, where limited ownership of signal systems may result in higher per signal maintenance costs. As part of the update to PennDOT Publication 191, *Guidelines for the Maintenance of Traffic Signal Systems,* standard shared maintenance and regional maintenance contracts should be developed for use by municipalities and regional consortiums. Existing Publication 191 provides a sample traffic signal maintenance contract. These sample specifications should be updated and municipalities should be encouraged to use them.

Tier I Solutions
Provide Incentives for Interjurisdictional Coordination Interjurisdictional coordination can help promote a regional, as well as a holistic system approach to managing and maintaining traffic signal systems. As part of this recommendation, funding preferences would be given to projects that are requested using collaborative funds by multiple entities. The approach would encourage MPOs/RPOs, counties, etc. to work closely together and to think beyond their political boundaries. This recommendation is one that should be carried out in balance so that it does leverage transportation resources but at the same time does not result in an oppressive degree of "strings attached."

OTHER RECOMMENDATIONS

In addition to the Tier 1 Solutions, many other potential solutions could provide short-term as well as long-term guidance for the operations and maintenance of traffic signal systems. More than 30 other recommendations are presented in **Section 8** of the full report. These solutions are important but were not examined in depth as those of the high priority. A few specific examples include:

- ❑ Consider the statewide implementation of a "systems" permit
- ❑ Streamline timing modification process
- ❑ Require timing plan development for homeland security/incidents/special events
- ❑ Revise HOP process to address corridors or signal systems in addition to the present single signal approach
- ❑ Revise HOP process to require signal fine-tuning through road bonds and/or escrow
- ❑ Implement a developer impact assessment/fee mechanism for operations and maintenance cost participation
- ❑ Produce an annual report on the "State of Signal Systems" to assess progress against goals and broad system level performance measures
- ❑ Create modernization/controller replacement program and interconnection programs
- ❑ Review sole source restrictions or consider innovative procurement methods to ensure "compatible" technology along key corridors
- ❑ Encourage more statewide training by vendors
- ❑ Establish hotline/ website for traffic signal concerns and questions.

CONCLUSIONS

The State Transportation Advisory Committee recognizes the effective and efficient movement of people and goods will require new investments, additional capacity, expanded infrastructure and improved operations of transportation facilities.

Improved transportation operations represent one especially important strategy given the relatively low costs in relation to the benefits. While each strategy is important and has its rightful place, efforts to improve operations should not be overlooked in this fiscally constrained environment.

This study fosters a comprehensive approach to assessing traffic signal improvement needs statewide and advancing a strategy that addresses those needs in some priority fashion. Improved traffic signal systems will help ease congestion, will enhance safety, and have indirect benefits such as improved air quality.

Pennsylvania signal systems are a $1 billion asset that are not managed and operated to their fullest. That is important context for evaluating the issues associated with the policies and practices of traffic signal systems. Key themes identified within this study include:

- Signal systems are an asset that should be better managed as such so that systems can be better planned, maintained and operated to reduce congestion
- Signal systems need be both maintained and operated. Operations include the development of appropriate operations parameters/standards, addressing special needs such as events, homeland security and incidents, and providing oversight to ensure systems are functioning properly and efficiently.
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- Signal systems cannot only be considered on a microscopic, jurisdictional level, but should also be considered on a corridor and regional level.
- A number of policy and procedures such as signal permitting need to be evaluated to address appropriate roles and responsibilities; the importance of signal systems and the highway occupancy permit process with regard to signal systems.
- Technology is rapidly changing, requiring continual training and education to ensure that signal systems can be designed, maintained and operated efficiently.
- Procurement policies can discourage technology implementation. Creative approaches are needed to both encourage continued research, and more importantly, to test and disseminate that research in an applied way throughout the Commonwealth.
- Funding for improved traffic signal systems should be considered as a part of future state transportation funding increases. This will serve to emphasize the importance of efficient operations. New funding can also leverage many other favorable results, including a performance-based approach for municipalities receiving funds based on updated standards.

  Although much can be accomplished without additional funding, a new funding source would allow recommendations to be implemented more quickly and to a far greater level as well as provide additional support for operations and maintenance.

TAC's recommendations reflect a systematic approach. Although many of the recommendations can be pursued individually, most recommendations are inter-related and the maximum benefit would be achieved through a systematic approach. TAC believes increased funding for traffic signals is not only justified on a benefit-to-cost basis, but fits with the Secretary's direction of improving the efficiency and effectiveness of existing facilities.

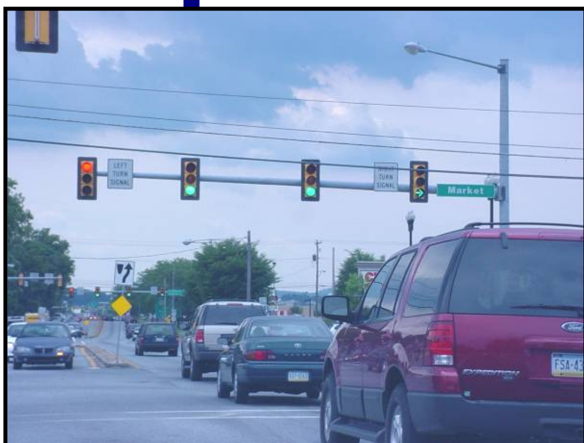
BENEFITS

By improving the coordination and performance of our traffic signal systems through better maintenance, operations and management practices, the following benefits can be realized:

- Reduced congestion on many of our major arterials
- Optimize the capacity of our existing infrastructure
- Improved air quality and decreased fuel consumption
- Reduced congestion-related crashes
- Improved response of emergency vehicles/services
- Promote more efficient transit system(i.e., transit signal preemption which allows transit vehicles to control signals)
- Respond to non-recurring special needs such as incident management, homeland security and special events
- Improved regional cooperation on signal system management and related transportation issues
- Improved utilization of existing and future resources by better planning, deploying and managing signal systems
- Stimulate economic development by making our roadways and our cities more accessible.

1. Introduction

1.1. Acknowledgements



The consultant team would like to thank the State Transportation Advisory Committee (TAC), the Study Task Force, the Technical Working Group, and the Technical Advisors for their active participation and insight during the various stages of this study. Special thanks are extended to the PennDOT staff that provided assistance, support, and information along the way.

1.1.1. TAC Membership

The duties and powers of the State Transportation Advisory Committee include consulting and advising the State Transportation Commission and the Secretary of Transportation on behalf of all the transportation modes of the Commonwealth.

The duties and powers of the State Transportation Advisory Committee as taken from Act 120, dated May 6, 1970:

The State Transportation Advisory Committee consists of the Secretary of Transportation, the Executive Director of the Governor's Policy Office, the Chairman of the Public Utility Commission, the Secretary of Community & Economic Development, the Secretary of Education, the Secretary of Environmental Protection, the Secretary of Agriculture, two members of the House of Representatives appointed by the Speaker and who are not members of the same political party, two members of the Senate appointed by the President Pro Temp and who are not members of the same political party, and eighteen additional public members.

The Governor shall appoint seven public members, the President Pro Temp of the Senate and the Speaker of the House of Representatives each shall appoint six public members to the State Transportation Advisory Committee. The public members must have recent and extensive experience and knowledge in the fields of transportation of people and goods from industry, labor, academic, consulting, research sources and the appointing authorities shall give due consideration to insure a balanced representation by facilities and modes for air, land, and water transportation as they exist in the Commonwealth, both public and private. Members are appointed for terms of three years. Any person appointed to fill a vacancy shall serve for only the unexpired term. Any member of the committee may be appointed to succeed himself. The Governor annually designates the chairman from among the public members.

*The State Transportation Advisory Committee meets on the first Monday in February of each year and holds at least three additional meetings during the calendar year**. It shall have the power and its duty shall be to consult with and advise the State Transportation Commission and the Secretary of Transportation in behalf of all the transportation modes of the Commonwealth.** The State Transportation Advisory committee aids and assists the State Transportation Commission and the Secretary of Transportation in the determination of goals and the allocation of available resources among and between the alternative modes in the planning, development and maintenance of programs, and technologies for transportation systems and to advise the several modes the planning, programs and goals of the department, and the State Transportation Commission.*

The following were members of the State Transportation Advisory Committee during the duration of this study:

State Transportation Advisory Committee
Member Listing – November 2004

- Mr. H. Michael Liptak, Chairman, State Transportation Advisory Committee, Highway Equipment & Supply Company
- Honorable Allen D. Biehler, Secretary, PA Department of Transportation
- Dr. Roy E. Brant, Ph.D.
- Mr. Brad Cober
- Ms. Donna Cooper, Director, Governor's Policy Office - Alternate: Ms. Joanne Denworth
- Honorable Wendell F. Holland, Chairman, PA Public Utility Commission - Alternate: Mr. David Hart
- Dr. Marion B. Fox, Ph.D.
- Mr. Anthony V. Herzog
- Honorable Richard A. Kasunic, Senate of Pennsylvania - Alternate: Mr. Stephen M. DeFrank
- Mr. Joseph Mangarella
- Honorable Kathleen McGinty, Secretary, Department of Environmental Protection - Alternate: Ms. Barbara Sexton
- Honorable Anthony J. Melio , House of Representatives - Alternate: Ms. Anne Titus
- Honorable John D. Payne. House of Representatives
- Honorable Dr. Francis V. Barnes, Secretary, Department of Education - Alternate: Mr. Robert Roush
- Mr. Anthony J. Ross
- Mr. Jack Rutter
- Mr. Richard L. Shaw
- Mr. David Sims, P.E.
- Mr. Ronald G. Wagenmann
- Honorable Donald C. White, Senate of Pennsylvania
- Mr. Glenn E. Wolgemuth
- Honorable Dennis Wolff, Secretary, Department of Agriculture - Alternate: Mr. Fred Wertz
- Ms. Mary Worthington, Wellsboro Chamber of Commerce
- Honorable Dennis Yablonsky, Secretary, Department of Community and Economic Development - Alternate: Mr. Paul Opiyo
- Ms. Anita Everhard, Executive Secretary State Transportation Advisory Committee

1.1.2. Task Force Members and Technical Advisors

The Task Force consisted of participants from TAC as well as invited participants. The Task Force was led by Chairman Ron Wagenmann who serves on the TAC. Ron is the Township Manager for Upper Merion Township, Montgomery County which owns and maintains more than 70 signalized intersections.

The Task Force was supported by Technical Advisors who work with signal systems on a daily basis.

Task Force Chairman

- Ronald G. Wagenmann, TAC Member

Members

- H. Michael Liptak, TAC Chairman
- Jack Rutter, TAC Member
- Dr. Roy E. Brant, TAC Member
- Joseph Mangarella, TAC Member
- Larry King, PennDOT Deputy Secretary for Planning
- Craig Reed, PennDOT, Director of the Bureau of Highway Safety and Traffic Engineering (BHSTE)
- Robert J. Janecko, PennDOT Center for Program Development and Management
- James Arey, PennDOT Center for Program Development and Management
- George Marcinko, Manager East Hempfield Township, Pennsylvania State Association of Township Supervisors (PSATS) – Alternate James Wheeler PSATS

Technical Advisors

- Doug Tomlinson, PennDOT, BHSTE
- Bill Laubach, PennDOT, BHSTE
- Tom Walter, PennDOT, Engineering District 5-0

Consultant Staff

- Keith Chase, Gannett Fleming, Project Principal
- Bob Taylor, Gannett Fleming, Project Manager
- Mark Metil, Gannett Fleming
- Cindy Kucharcik, Gannett Fleming
- Charnelle Hicks, CH Planning
- Ben Ginsberg, CH Planning
- Jeremy Goldstein, CH Planning

1.2. THE HISTORY OF TRAFFIC SIGNAL SYSTEMS

Traffic signals date back as early as 1908, however common deployment of traffic signals and signal systems began in the 1920's.

Even in the "horse and buggy" era, city streets were often congested. Police officers were stationed full time at busy intersections to control traffic. Congestion worsened with the introduction of the automobile.

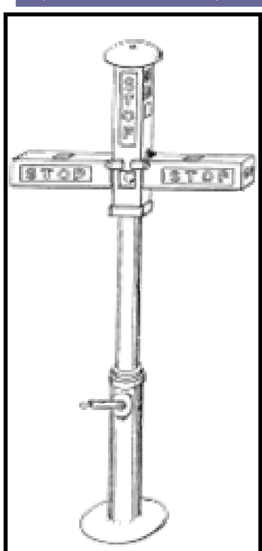
As a relief measure, the traffic officer was stationed in the center of the main avenue to separate the horses from the "self-propelled carriages." This soon became a complicated process and the "right-of-way" philosophy was introduced. However, people often did not know "who went first," and many accidents began resulted.[1]

- **Traffic signal** – a power-operated traffic control device by which traffic is warned or directed to take some specific action
- **Signal installation** – all of the equipment or material involved in the control of traffic at one intersection by a traffic signal
- **Signal system** – two or more signal installations operating in coordination

A 1920 Traffic Signal designed by William L. Potts (www33.brinkster.com)

Garrett Morgan holds the patent for the first automatically controlled traffic light. This traffic signal was a T-shaped pole that featured three positions: Stop, Go and an all-directional stop position. The all-stop position halted traffic in every direction to allow pedestrians to safely cross streets. This signal was first used in Cleveland, Ohio at the intersection at 9th and Euclid in 1908.[2]

William L. Potts of the Signal Bureau, Detroit Police Department set out to design the world's first three-color, four-direction, electric traffic lamp. A yellow indication light was used to warn traffic of the change from red to green and vice versa. The traffic lamp was installed at the intersection of Woodward Avenue and Fort Street, Detroit, Michigan in October, 1920. The signal remained in use until 1924 and became a part of the world's first synchronized signal system. This system extended from Jefferson to Adams on Woodward Avenue and was controlled manually from a tower at Woodward and Michigan.[3]



Garrett Morgan's hand-cranked traffic signal. (www33.brinkster.com)

Another source claims that the first coordination development was the simultaneous traffic signal system which was installed in Houston, Texas in 1922.[4] In this system, all the traffic signals on the main roadway would change to green at the same time.

Many cities in Pennsylvania were among the first to install traffic signals. Harrisburg installed "Attica" signals as early as 1924. **Many signals dating back as early as the 1940's are still in use in some jurisdictions in Pennsylvania.** [5]

Traffic congestion, signal coordination, and safety are still major concerns; however, roadway traffic volumes have been steadily increasing, and Pennsylvania is no exception. The installation or upgrading of traffic signals is still one improvement to help alleviate this problem. Traffic signals must be efficiently operated and properly maintained to yield their true benefits.

1.3. Background

Currently, there are more than 13,600 signals in Pennsylvania. This Transportation Advisory Committee study examines Pennsylvania's Traffic Signal Systems and the policies and practices associated with them. Traffic signal systems are the sole focus of the study in relation to congestion. Traffic signals cannot be studied in this broad manner without considering other aspects of the Commonwealth's entire transportation system.

Issues and recommendations will be considered and identified that directly or indirectly have implications for safety, intelligent transportation systems (ITS), traffic control centers, and/or other facets of the total transportation system that interface with traffic signals.

More than two out of five adults in the United States report that traffic congestion is a problem in their communities, according to results from the U.S. Department of Transportation's Bureau of Transportation Statistics Omnibus Household Survey (2002)

1.4. Objectives

In order to develop a beneficial study, it was important to first identify objectives of this study.

- Produce an evaluation of relevant issues associated with the policies and practices of traffic signal systems throughout the Commonwealth.
- Identify alternatives to reduce congestion.
- Make feasible recommendations for ways traffic signal systems might be better planned, deployed, and managed to improve safety and congestion management.

This section summarizes the results of the first phase of the study process – General Assessment. It discusses issues that were identified through structured stakeholder involvement and research.

1.5. Study Methodology

The traffic signal system study was developed using a three phase process:

- **Phase I – General Assessment** – This phase entailed stakeholder involvement and research for the purpose of issue identification and to focus ensuing research.
- **Phase II – Issues Evaluation** – Phase II involved the evaluation and prioritization of the issues identified by the stakeholders and Task Force.

- **Phase III- Final Report Development and Presentation** – The final phase involved the development of a study final report and a presentation to the TAC.

Distinct tasks that were carried out included:

- Task 1 – Issue Identification/Definition & Initial Prioritization – Task 1 involved the organization and facilitation of a July 1, 2004 stakeholder workshop. Stakeholder participants identified issues related to Pennsylvania's Traffic Signal Systems. This task, along with the workshop results, is described in more detail in **Section 3.2** of this document.
- Task 2 – Basic Amplifying Research & Benchmarking – The consultant team conducted initial research based on the issues identified in Task 1. Research results were used to determine best and innovative practices and are identified in this document. As part of this research, a select group of state departments of transportation were contacted as well as PennDOT districts.
- Task 3 – Task Force Issue Prioritization - This Task entailed a meeting with the TAC Study Task Force to review research as well as to prioritize the issues to proceed with Phase II.

Phase II provided an in-depth evaluation of all issues identified during the first phase. This information was used to shape the recommendations of this report (**see Sections 7 and 8**). Specific tasks for Phase II included:

- Process Mapping – A tool to graphically and systematically analyze the Phase I defined issues and their interrelationships. This was used to provide a conceptual presentation of each issue. It was also used as a means for identifying problems, constraints, potentially conflicting or sub-optimal policies and practices, and recommended solutions.
- Research and Analysis – In-depth research and evaluation supporting the development of the findings and recommendations was conducted.
- Findings and Recommendations – The findings and recommendations are organized into the categories that were identified in Phase I and are presented in **Sections 7 and 8** of this report.
- Task Force Evaluation – This task provided for Task Force input and direction prior to completing the feasibility assessment. As part of this task, the Task Force informally ranked 50 plus recommendations.
- Feasibility Assessment – This task assessed the practical feasibility and related considerations for each of the recommendations identified in this report.

The third and final phase of the study process entailed the development of a draft final report which took into consideration all information collected during the first two phases of the study process. The report was presented to the Task Force for review. Presentations will be made to the full TAC and the State Transportation Commission for closeout.

2. BACKGROUND AND PERSPECTIVE

2.1. OVERVIEW OF CURRENT POLICIES AND PRACTICES

There are 119,986 road miles in Pennsylvania. Of these, 33% is state owned road miles (PennDOT - 39,935 miles).The remaining mileage is primarily locally owned road miles.[6]

Pennsylvania has more than 13,600 traffic signal installations in operation statewide.[7] Municipalities own, operate, and maintain traffic signals within the state. As such, the condition of signals varies depending on the amount of resources allocated to ownership, maintenance, and operations. Moreover, in some locations, signals systems (which interconnect individual signals) may not be necessary to accommodate the volume of traffic.

Pennsylvania has 2,655 general-purpose local governments, each with separate and distinct jurisdiction.[8] In order for a traffic signal to be installed, a municipality must prove (to PennDOT engineers) that the signal or signals are warranted for a specific intersection per PennDOT guidelines.

- Generally, the municipality or developer will hire a consultant to conduct a traffic study.
- The study must verify that at least one of several national warrants for the installation of a traffic signal is satisfied.
- Based on the outcome of the traffic study, the signal may be designed and PennDOT will issue the traffic signal permit to the municipality.
- Once PennDOT issues a traffic signal permit, in many cases the municipality is responsible for purchasing, installing, operating, and maintaining that traffic signal. On state highway projects involving signal installations, PennDOT often pays for the design and installation of the traffic signal, but the municipality is still responsible for ownership, operations and maintenance.

41 states (82%) have some form of state ownership or maintenance responsibilities

Traffic signal ownership in Pennsylvania is unlike most other states. The Southwestern Pennsylvania Commission (SPC) identified 41 states (82%) having some form of state ownership or maintenance responsibilities for traffic signals on state highways. Most states have a tiered ownership where the traffic signals are owned by the level of government that owns the road/street. Other states allow local ownership only if the local authority has staff qualified to certify the signals based on national standards.[9]

Signals in Pennsylvania are governed by the following publications:

- National Manual on Uniform Traffic Control Devices (MUTCD)
- PennDOT Publication 68 (Official Traffic Control Devices); 67 PA Code, Chapter 211

- PennDOT Publication 201 (Engineering and Traffic Studies); 67 PA Code, Chapter 201
- Title 75, Pennsylvania Consolidated Statues (the Vehicle Code)
- PennDOT Publication 149 (Traffic Signal Design Handbook)
- PennDOT Publication 191 (Guidelines for the Maintenance of Traffic Signal Systems)
- PennDOT Publication 148 (Traffic Standards – Signals, TC-7800 Series)
- PennDOT Publication 408 (PennDOT Specifications).

2.2. FUNDING AND OWNERSHIP CONSIDERATIONS

2.2.1. Ownership and Responsibilities

The Commonwealth of Pennsylvania neither owns nor operates traffic signals. Regardless of whether a traffic signal is located on a state or local road, the municipality has responsibility for the ownership, operation, and maintenance of those traffic signals that are within their municipality. PennDOT has oversight of the signals through the conditions of the issued permit.

Ownership by PennDOT District

As previously mentioned, Pennsylvania has more than 13,600 traffic signal installations.[10] **Exhibits 2.1** and **2.2** detail the breakdown of traffic signals by PennDOT District.

Exhibit 2.1: Map of Traffic Signals by PennDOT District

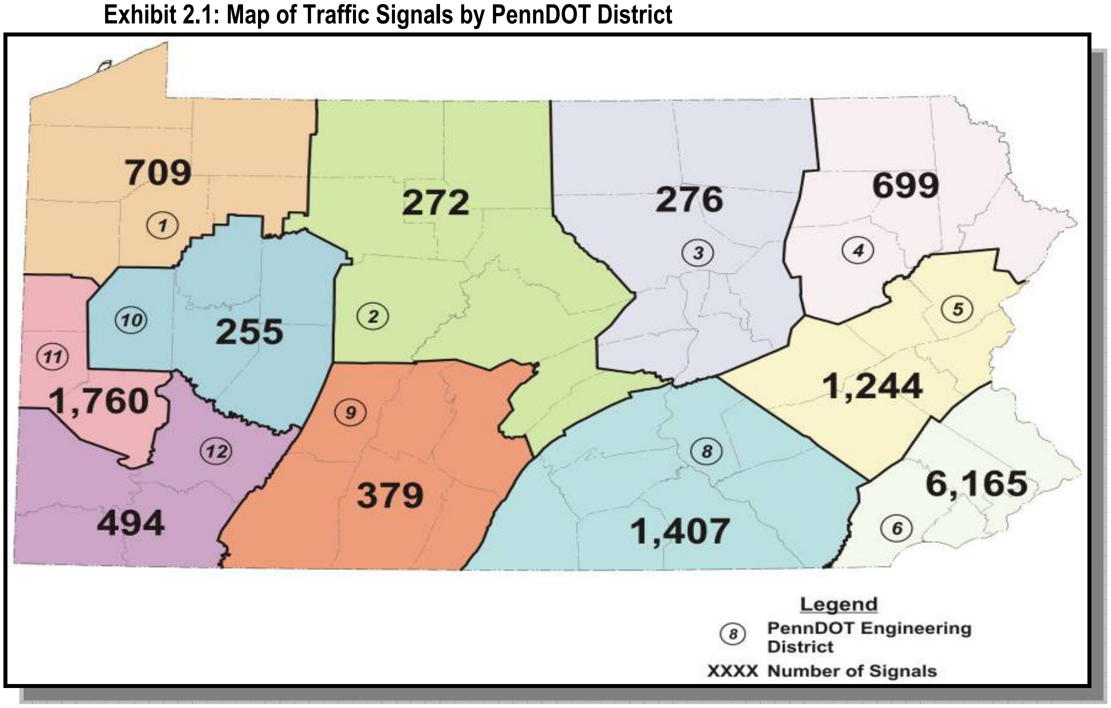


Exhibit 2.2: Summary of Traffic Signals by PennDOT District

District	Number of Signal Installations	Percentage of Statewide Signals
1	709	5.2
2	272	2.0
3	276	2.0
4	699	5.1
5	1,244	9.1
6	6,165	45.1
8	1,407	10.3
9	379	2.8
10	255	1.9
11	1,760	12.9
12	494	3.6
TOTAL	**13,660**	**100.0**

*Orange shading represents highest two values – 58% of the signals are in the Philadelphia and Pittsburgh metropolitan areas.

77.4% of signals are located in PennDOT Districts 5, 6, 8 and 11

45.1% of traffic signals are located in District 6, and 77.4% of all signals are located in Districts 5, (Allentown/Bethlehem region), 6 (Philadelphia region), 8 (south, central PA region), and 11 (Pittsburgh region).The remaining 22.6% of traffic signals are located in the remaining 7 PennDOT Districts with District 10 having the lowest percentage at 1.9%.

Ownership by County

As with PennDOT Engineering Districts, the breakdown of traffic signals at the county level illustrates several key trends (**see Exhibit 2.3**).

As expected, PennDOT's inventory of traffic signals indicate that the more urbanized counties have the greater concentration of traffic signals, due to concentrated populations and development and the associated levels of traffic. Rural counties with smaller populations have fewer signalized intersections.

- For example, Philadelphia County (2,959 traffic signals; 21.7% of total signals statewide), Allegheny County (1,517 traffic signals; 11.1% of total signals statewide), and Montgomery County (1,385 traffic signals; 10.1% of total signals statewide) are the most heavily populated counties in Pennsylvania, and, therefore have the greatest concentration of traffic signals.
- By contrast, rural counties such as Cameron, Fulton, Juniata, Potter, and Sullivan counties have a combined total of just 11 traffic signals. There are no signals im Perry and Forest counties ate the present time.

Exhibit 2.3: Traffic Signals in Pennsylvania Counties

County	Number of Signals	Percent of Total Signals Statewide
Adams	42	0.31%
Allegheny	1,517	11.11%
Armstrong	46	0.34%
Beaver	148	1.08%
Bedford	26	0.19%
Berks	398	2.91%
Blair	166	1.22%
Bradford	18	0.13%
Bucks	630	4.61%
Butler	112	0.82
Cambria	123	0.90%
Cameron	2	0.01%
Carbon	23	0.17%
Centre	113	0.83%
Chester	501	3.67%
Clarion	21	0.15%
Clearfield	55	0.40%
Clinton	22	0.16%
Columbia	42	0.31%
Crawford	88	0.64%
Cumberland	203	1.49%
Dauphin	238	1.74%
Delaware	690	5.05%
Elk	20	0.15%
Erie	392	2.87%
Fayette	88	0.64%
Forest	0	0.00%
Franklin	93	0.68%
Fulton	2	0.01%
Greene	22	0.16%
Huntingdon	23	0.17%
Indiana	55	0.40%
Jefferson	21	0.15%
Juniata	3	0.02%

County	Number of Signals	Percent of Total Signals Statewide
Lackawanna	252	1.84%
Lancaster	418	3.06%
Lawrence	95	0.70%
Lebanon	92	0.67%
Lehigh	402	2.94%
Luzerne	368	2.69%
Lycoming	102	0.75%
McKean	21	0.15%
Mercer	133	0.97%
Mifflin	33	0.24%
Monroe	70	0.51%
Montgomery	1,385	10.14%
Montour	14	0.10%
Northampton	256	1.87%
Northumberland	48	0.35%
Perry	0	0.00%
Philadelphia	2,959	21.66%
Pike	19	0.14%
Potter	3	0.02%
Schuylkill	95	0.70%
Snyder	17	0.12%
Somerset	39	0.29%
Sullivan	1	0.01%
Susquehanna	16	0.12%
Tioga	10	0.07%
Union	24	0.18%
Venango	55	0.40%
Warren	41	0.30%
Washington	136	1.00%
Wayne	31	0.23%
Westmoreland	248	1.82%
Wyoming	13	0.10%
York	321	2.35%

Source: PennDOT, Bureau of Highway Safety and Traffic Engineering Signal Database, 2004.
*Orange shading represents counties with 10% or more

92% of the municipalities owning traffic signals have 25 or less signals; 80% have 10 or less; 64% have five or less; and 28% have one signal

Ownership at Municipal Level

There are 2,655 municipalities in Pennsylvania. 1,192 municipalities or 46.5% that have at least one traffic signal (**see Exhibit 2.4**). 53.5% of Pennsylvania's municipalities do not own a traffic signal.

Exhibit 2.4: Municipal Ownership Breakdown

Number of Signals	Number of Municipalities	Percentage of All Municipalities
>150	4	0.16%
51 to 150	24	0.94%
26 to 50	65	2.53%
11 to 25	141	5.50%
6 to 10	190	7.41%
2 to 5	433	16.88%
1	335	13.06%
SUBTOTAL	**1192**	**46.47%**
0	1373	53.53%
TOTAL	**2655**	**100.00%**

Source: PennDOT, Bureau of Highway Safety and Traffic Engineering, 2004.

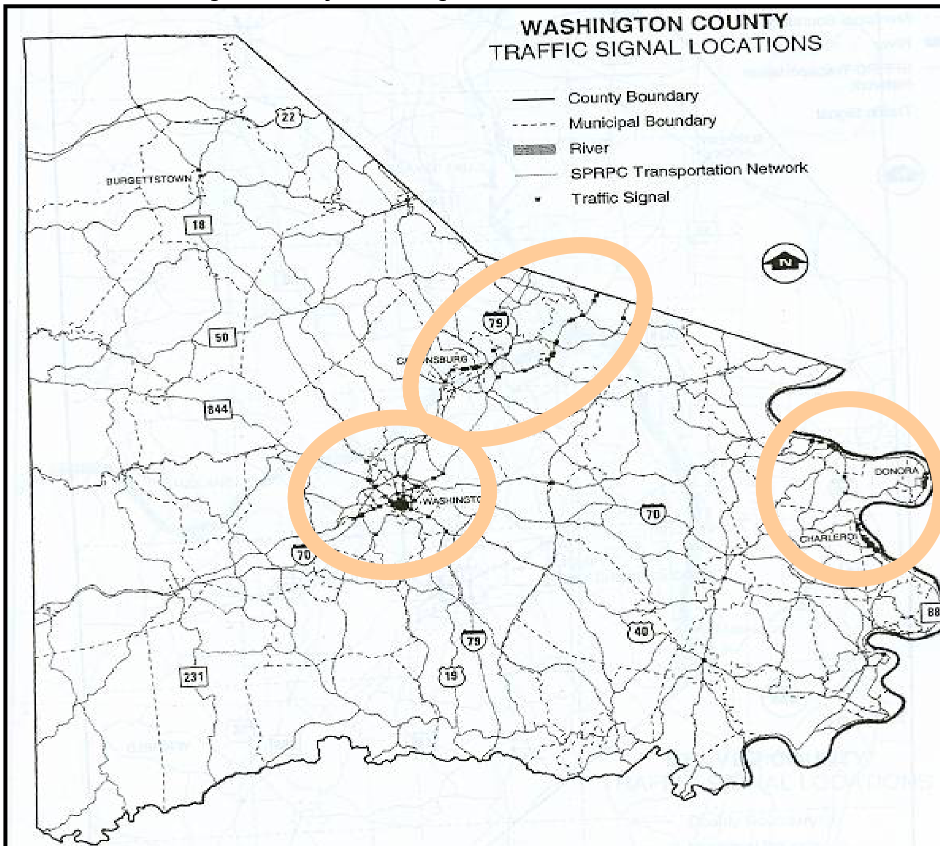
As can be seen, there are 433 municipalities with 2-5 traffic signals. In fact, of the 1,192 municipalities in the state with traffic signals, 1,099 or 92% have 25 or fewer signals. It is interesting to note, the Institute of Transportation Engineers estimates that for every 30 signals one full-time technician is needed to effectively maintain and operate them.

At the other end of the spectrum, only 93 municipalities own more than 25 traffic signals,[11] and only four own more than 150 with Philadelphia owning nearly 3,000 and Pittsburgh owning more than 600.

With the vast numbers of municipalities having responsibility for traffic signals coupled with the fact that most municipalities own a small number of signals, it is understandable that there are many issues associated with the effective management of traffic signals. Outreach regarding training, technology and effective use must reach more than a thousand agencies. It was noted by one stakeholder that some of these municipalities are unaware they even own the traffic signals in their municipality.

A good example of the location of municipal signal ownership is found in Washington County, located in southwestern Pennsylvania. . Washington County has a concentration of traffic signals in and around the City of Washington, and in Canonsburg, Chaleroi, and Donora Boroughs (**see Exhibit 2.5**), but has few signals outside of these areas.

Exhibit 2.5: Washington County Traffic Signals



Source: Southwestern Pennsylvania Regional Planning Commission, 1996.

2.2.2. Funding and Economic Considerations

Budget Crisis: Pittsburgh's traffic engineer was laid off due to funding issues.

Many municipalities do not have the funding or technical expertise to operate and maintain traffic signals.[12] As traffic patterns change over time and equipment ages, the funding and manpower required to effectively operate and maintain a signal system tends to increase. Typically, retiming of traffic signals and general preventative maintenance often does not occur.[13] Maintenance issues focus on replacing bulbs and keeping the signal in minimum operating conditions. Effective operations (timing updates, etc.) and use of signal systems (monitoring and adjusting, etc.) are often sacrificed.

Capital and Operating Budgets

There is a variety of funding mechanisms available to design, build, maintain, and operate traffic signal systems. **Funding of traffic signals in Pennsylvania may come from local capital and operating budgets, state taxes, regional funding pools, state programs, and private developers. Municipalities should include the maintenance and**

operation of traffic signals as a specific line item in their capital and operating budgets.

The City of Philadelphia includes signal material requisition and system synchronization as specific line items in the City's capital budget. By contrast, the City budgets for all traffic engineers through the Streets Department's operating budget.[14] Swatara Township, in Dauphin County, funds construction of traffic signals through the Township's general fund, while operation and maintenance is funded through the Liquid Fuels fund.[15] Other municipalities have reduced the staff dedicated to signal systems due to funding constraints. For example, in January 2004, the City of Pittsburgh laid off its traffic engineer, leaving Pittsburgh any traffic engineer to oversee its 658 traffic signals.[16]

Liquid Fuel Tax

Pennsylvania's Liquid Fuel Tax is presently a 12 ¢ per gallon levy imposed on all liquid fuels and fuels used or sold by distributors within the Commonwealth.[17] Each county receives a percentage of the money paid into the liquid fuels tax fund, and each county is authorized to allocate money from the county liquid fuels fund to its municipalities.[18] The liquid fuels statute enables money from the levy to be spent on the acquisition, maintenance, repair, and operation of traffic signs and signals.[19] The allocation of the liquid fuels considers vehicle miles, but does not consider operational items such as the number of signals or the presence of ITS.

Transportation Improvement Program

Traffic signals may also be funded through the regional Transportation Improvement Program (TIP). The TIP is the regionally agreed upon list of priority projects for near-term capital funding. Typically, TIP-funded traffic signal projects are more traffic volume driven or are part of larger and more comprehensive highway improvement projects, rather than being solely a traffic signal or efficiency project. Furthermore, the TIP is sometimes used for the design and construction of new signal systems as independent projects or as part of other highway projects.

Traffic Signal Enhancement Initiative

PennDOT's Traffic Signal Enhancement Initiative (TSEI) called for PennDOT to "partner with municipalities to identify traffic signals that need to be retimed, upgraded, or better integrated into an overall congestion management strategy."[20]

The goal of the TSEI is to reduce travel times and delay on specified signalized corridors. The TSEI seeks to optimize traffic flow through signalized intersections. All projects under the TSEI must illustrate that traffic flow is the primary focus; however, safety enhancements may be included as an additional benefit. Although PennDOT focuses on corridor-based projects, it will consider improvements to grid systems or isolated intersections, if sufficiently justified.

Implementation of the TSEI began with a $1 million set aside in PennDOT's 2001-2002 and 2002-2003 Highway Administration Business Plans. For fiscal years 2003-2004 and 2004-2005, $1.2 million has been allocated to the TSEI. Projects for the TSEI are submitted by the Traffic Signal Section in each PennDOT District Traffic Unit. Each District may annually submit a maximum of two municipally-supported projects for consideration.[21]

Private Developers

PennDOT regulates access to state roads through the issuance of Highway Occupancy Permits (HOP). The purpose of the HOP is "to regulate the location, design, construction, maintenance, and drainage of access driveways, local roads, and other property within state highway right-of-way for the purpose of security, economy of maintenance, preservation of proper drainage and safe reasonable access."[22]

In PA, annual operation & maintenance expenditures range from $600 - $4,700 per signal based on those surveyed.

A HOP must be obtained from PennDOT when someone wants to alter a driveway, local road, or drainage facility, or connect onto a state highway right-of-way. As part of the process, the PennDOT Engineering District may require the applicant, usually a private developer, to conduct a traffic impact study in order to define the magnitude of potential impacts of the proposed development on traffic operations. The traffic impact study also serves to determine the necessary improvements to provide for mitigation of traffic due to the proposed development. If traffic impacts require new or upgraded traffic signals, PennDOT will typically require the developer to pay for the design and installation of such signals. In many cases, the developers are not required to evaluate the entire signal system, but only signals (or new signals) influenced by their development. Often maintenance and operations is overlooked when developers and municipalities discuss transportation improvements. This situation is exacerbated in tax-free areas when a developer may not have to pay any taxes, which could be used for signal maintenance and operations.

Cost of New Signals

The cost of a new traffic signal varies widely across the United States from $18,000 in Wilmington, NC to $200,000 in Las Vegas, NV, where one mile of interconnect capacity is built with each signal. There is a great deal of variation in what it costs to build a traffic signal since the size and complexity of each design varies.[23] It is estimated that the average cost to build a traffic signal is $75,000-$125,000.[24] Signals with elements such as mast arms, multiple loops and interconnection have higher construction costs.

Cost of Signal Maintenance

According to the Institute of Transportation Engineers, the average annual maintenance cost needed per signal was $2,760.[25]. The Institute of Transportation Engineers also estimates that signal maintenance and operations are under funded by 20%.

In Pennsylvania, municipalities generally fund traffic signal operation and maintenance through their local operating budgets. The level of municipal expenditures for capital improvements and maintenance related to traffic signals varies significantly.[26] According to the SPC, the least financially able municipalities spend as little as 1/100th the level of support for traffic signals as the most financially capable communities. According to the report, traffic signals in the most financially-strapped communities appear to be the most neglected.[27] Annual municipal expenditures per traffic signal ranged from $4,700 for "stately" communities to $600 for "distressed" communities.[28]

Sample approximate annual municipal expenditures per traffic signal in Pennsylvania:

City of Bethlehem, Northampton & Lehigh Counties:	$1,200
Cheltenham Township, Montgomery County:	$740
Cranberry Township, Butler County:	$1,200
Exeter Township, Berks County:	$606
Manheim Township, Lancaster County:	$2,825
Shaler Township, Allegheny County:	1,280
Swatara Township, Dauphin County:	$2,372 - $3,560
Upper Merion Township, Montgomery County:	$3,700
West Chester Borough, Chester County:	$2,169
City of Philadelphia, Philadelphia County:	$1,870

It should be noted that these costs are based on responses received from study surveys when asked about operations and maintenance. The survey asked respondents to include utility costs.

Cost of Congestion

Traffic congestion is defined as a condition of traffic delay because the number of vehicles trying to use a road exceeds the design capacity of the traffic network. This condition generally arises when traffic flow is slowed below reasonable speeds.[29] Traffic congestion is widely viewed as having a range of negative impacts on people and goods movement, the economy, and the environment.

5% of congestion delay hours are caused by traffic signals.

The Federal Highway Administration (FHWA) found that congestion results in 5.7 billion person hours of delay annually in the United States.[30] **Further, the individual cost of congestion exceeded $900 per driver in 1997, resulting in over $72 billion in lost wages and fuel**.[31] Further, the Texas Transportation Institute found that the annual costs of congestion in the Philadelphia and Pittsburgh Urban Areas were $1.5 billion and $255 million respectively.[32] Importantly, FHWA estimates that 5% of the 4 billion congestion delay hours per year are attributable to traffic signals.[33] I**t can be estimated that the annual congestion impacts equate to $12,000 in delay costs per signal nationally**.

There are two types of business costs that are considered when analyzing the effects of traffic congestion on the economy:

- Change in direct cost of production and
- Additional change in accessibility to specialized inputs.

Both take into account commuter and business delivery movements between locations. A reduction in transportation costs directly translates into a reduction in the cost of obtaining workers and delivering products and services to customers, and therefore, a reduction in total production costs. Additionally, lower transportation costs change the distribution of shipments and trips as more specialized workers and customer markets become available. As such, a reduction of costs occurs since companies are able to use labor that more specifically meets their production needs and serves broader customer markets.[34]

The actual impacts of traffic congestion upon the economy differ by metropolitan area, depending upon economic profile and business location patterns.[35] The Transportation Research Board (TRB) conducted a case study of the Philadelphia metropolitan region which analyzed traffic congestion as it relates to business delivery and commuting costs. In Philadelphia, congestion increased the direct costs of freight and service delivery, specifically truck shipping. Congestion caused additional costs associated with unreliable travel times and causes companies to substitute among inputs to adjust to changes in accessibility among different suppliers.[36]

The TRB study found that congestion impacts differ depending upon the nature of the congestion scenario. Congestion occurring in Center City Philadelphia largely affected those service oriented Center City businesses. Many Center City businesses rely upon incoming deliveries of supplies. Congestion occurring equally throughout the region also produced economic impacts that were most pronounced in Center City and in the most densely industrialized areas, which are primarily dependent on incoming trucks for deliveries of supplies.[37] Similarly, the TRB study found that companies with greater dependence on less-specialized occupations, such as clerical workers, tend to be hurt relatively less by congestion than those with requirements for more specialized occupations, such as executives or precision production occupations.[38]

2.3. UNDERSTANDING THE STATEWIDE CONTEXT

When comparing Pennsylvania's policies and practices for signal systems with other states, the context and make-up of the state must be considered to understand the similarities and differences. Specifically, roadway and signal ownership must be considered since it can have a significant impact on how signals are maintained and operated and how transportation improvements are funded.

PA has the 5th most state transportation agency owned road miles in the U.S.

2.3.1 Roadway Ownership

Pennsylvania has 119,986 miles of roadway. PennDOT owns 39,935 road miles or 33% of all road miles within the state. In fact, Pennsylvania has the fifth most state-owned road miles in the U.S.[39] In addition; there are 75,104 miles of municipally owned roads in Pennsylvania.[40]

Ownership of roads varies from state to state. Some states have strong state ownership while others defer to county or municipal ownership of their roadway systems. **Exhibit 2.6** depicts the various levels of road ownership.

Ohio and Florida have a comparable amount of total road miles to Pennsylvania, but have significantly less state owned roads. West Virginia has a third of the total miles as Pennsylvania, but nearly all are state owned.

Exhibit 2.6: Public Road Length – Miles by Ownership

State	State Highway Agency	County	Town, Township, Municipal	Other Juris.	Federal Agency	Total	Percent Rural
Pennsylvania	***39,935***	***287***	***75,104***	***3,715***	***945***	***119,986***	***71%***
Alabama	10,900	58,708	23,938	162	733	94,441	78%
Alaska	5,677	3,360	1,714	724	2,153	13,628	87%
Arizona	6,651	19,808	16,838	121	11,828	55,246	67%
Arkansas	16,369	65,370	13,729	1	2,663	98,132	89%
California	15,201	65,758	71,297	3,070	13,444	168,770	49%
Colorado	9,092	54,833	13,492	1,217	7,218	85,852	83%
Connecticut	3,717	-	16,915	273	4	20,909	43%
Delaware	5,122	-	685	1	6	5,814	66%
Dist. of Col.	1,429	-	-	19	85	1,533	0%
Florida	12,052	69,022	34,148	-	2,078	117,300	42%
Georgia	17,882	82,059	13,692	772	1,129	115,534	76%
Hawaii	945	3,159	-	56	118	4,278	51%
Idaho	4,955	14,959	2,211	15,830	8,354	46,309	91%
Illinois	16,247	16,471	104,718	667	254	138,357	73%
Indiana	11,193	66,755	16,090	-	-	94,038	79%
Iowa	9,727	89,137	13,943	515	113	113,435	91%
Kansas	10,380	111,608	2,414	10,196	127	134,725	92%
Kentucky	27,480	41,459	8,862	86	1,026	78,913	85%

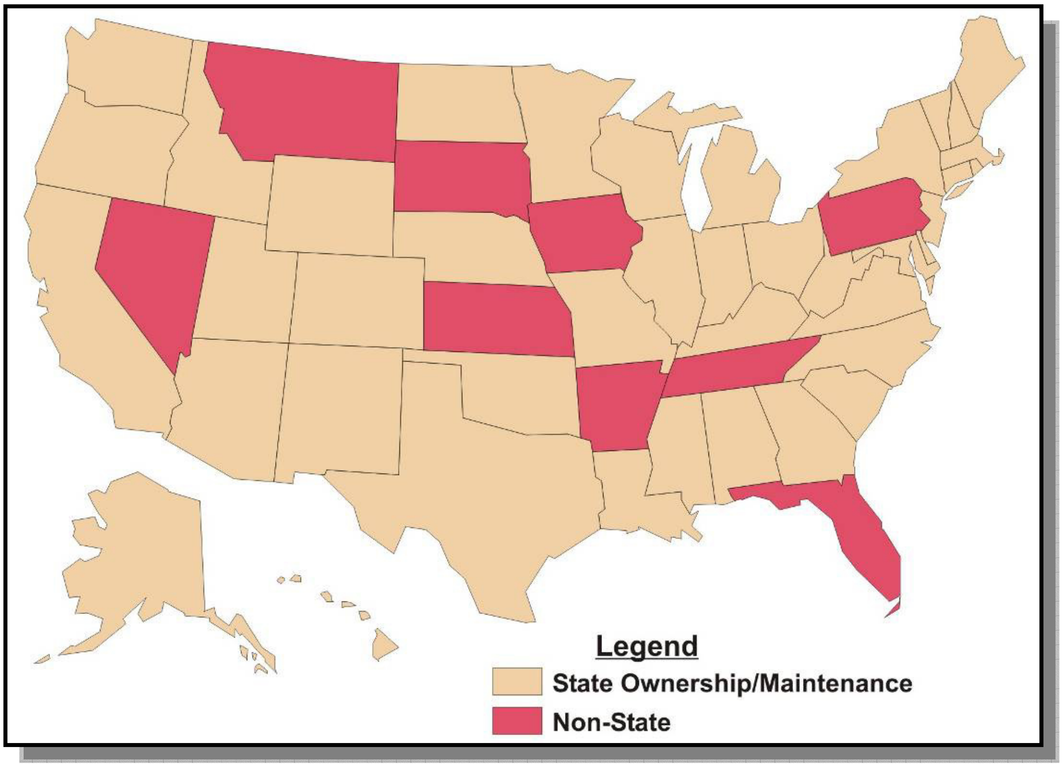
Exhibit 2.6: Public Road Length – Miles by Ownership

State	State Highway Agency	County	Town, Township, Municipal	Other Juris.	Federal Agency	Total	Percent Rural
Pennsylvania	***39,935***	***287***	***75,104***	***3,715***	***945***	***119,986***	***71%***
Louisiana	16,704	32,339	11,147	16	623	60,829	77%
Maine	8,403	-	13,896	200	172	22,671	88%
Maryland	5,131	20,328	4,463	269	431	30,622	53%
Massachusetts	2,843	5	31,704	746	110	35,408	35%
Michigan	9,725	89,600	20,732	-	1,732	121,789	75%
Minnesota	11,958	45,526	71,517	1,318	1,961	132,280	88%
Mississippi	10,663	53,243	8,907	136	752	73,701	89%
Missouri	32,425	71,131	19,662	2	1,104	124,324	86%
Montana	7,858	43,946	3,627	369	13,704	69,504	96%
Nebraska	9,993	60,896	21,421	297	159	92,766	94%
Nevada	5,447	25,932	4,025	511	2,741	38,656	85%
New Hampshire	4,000	-	11,341	31	137	15,509	81%
New Jersey	2,311	7,429	25,319	1,029	88	36,176	33%
New Mexico	11,414	38,804	2,208	145	7,312	59,883	90%
New York	15,038	20,349	76,105	1,373	96	112,961	64%
North Carolina	78,376	-	18,850	748	3,221	101,195	76%
North Dakota	7,378	10,153	68,346	21	693	86,591	98%
Ohio	19,294	29,170	65,293	3,241	270	117,268	71%
Oklahoma	12,267	81,031	18,165	1,181	49	112,693	88%
Oregon	7,590	33,455	9,823	4,762	11,154	66,784	83%
Rhode Island	1,114	-	4,925	3	10	6,052	22%
South Carolina	41,477	20,152	2,106	191	2,243	66,169	84%
South Dakota	7,840	36,196	37,513	59	1,952	83,560	97%
Tennessee	13,791	56,337	16,860	538	297	87,823	80%
Texas	79,346	142,504	78,314	138	464	300,766	73%
Utah	5,823	23,509	8,602	745	3,530	42,209	82%
Vermont	2,629	-	11,341	210	110	14,290	90%
Virginia	56,942	1,594	10,287	39	1,857	70,719	73%
Washington	7,048	40,397	14,131	11,993	7,416	80,985	78%
West Virginia	33,975	-	2,257	87	677	36,996	92%
Wisconsin	11,753	20,582	79,355	135	839	112,664	85%
Wyoming	6,760	14,320	2,024	866	3,322	27,292	91%
U.S. Total	**772,270**	**1,781,681**	**1,204,056**	**68,824**	**121,504**	**3,948,335**	**78%**

2.3.1. Traffic Signal Ownership

The 1996 SPC traffic signal study surveyed nationwide traffic signal ownership patterns and identified 41 states with some form of state ownership or maintenance over traffic signals (**see Exhibit 2.7**). Nine states, including Pennsylvania, have no state ownership or maintenance of traffic signals. In fact, every state bordering Pennsylvania has some form of state ownership or maintenance for traffic signals.[41]

Exhibit 2.7: Signal Ownership by State



Source: Southwestern Pennsylvania Commission, 1996

The states without state ownership in addition to Pennsylvania include:

- Arkansas
- Florida
- Kansas
- Iowa
- Montana
- Nevada
- South Dakota
- Tennessee

Sixteen states (**see Exhibit 2.8**) were contacted regarding their breakdown of road miles and signal ownership as they compare to Pennsylvania.

Exhibit 2.8: State Summaries – Traffic Signal Ownership

State	Summary
Florida	***In Florida, the counties own, maintain, and operate traffic signals***. *In Palm Beach County, the Department of Engineering and Public Works, Traffic Division is responsible for traffic signal maintenance and operations. The County has maintenance and operations agreements with almost all municipalities (excluding Palm Beach and Boca Raton). The County undertakes all traffic studies and makes recommendations on signal warrants. Traffic signals in Palm Beach County are mainly located on major state or county owned arterials. Those signals on state-owned roads are installed by the Florida Department of Transportation, however, maintenance and operations of these signals are transferred to the County. Where traffic signals occur at the intersection of two city roads, the County requires that the signals are funded by the city.*[42]
Kansas	***There are only 20 traffic signals owned by the Kansas Department of Transportation, located on high-speed limited access state owned rural roads.*** *All other signals are owned, maintained, and operated by either a city or county depending upon the ownership status of the road. Interestingly, traffic signals located on state owned roads that traverse a city, are the responsibility of that city, as long as the city's maintenance and operation does not interfere with the flow of traffic on the state highway system.*[43]
Iowa	***The state owns only 10 traffic signals all in rural counties and under special circumstances.*** *Otherwise, all traffic signals in Iowa are owned, maintained, and operated by either a county or city depending upon the type of road ownership.*[44]
Maryland	***In Maryland, the state has ownership, maintenance, and operational responsibility of traffic signals located on state roads***. *However, Montgomery County and the City of Baltimore own, maintain, and operate every traffic signal in the county or city regardless of road ownership.* ***Traffic signals located on county owned roads are owned, maintained, and operated by that county***. *Municipalities own, maintain, and operate those traffic signals located on local roads. State ownership, maintenance, and operations preempt the counties and municipalities at intersections.*[45]
Missouri	*The state of Missouri owns and maintains all signals on state roads, while municipalities own and operate signals on city roads. Cities also operate timing plans for intersections where state and municipal roads cross.*
New Jersey	***The New Jersey Department of Transportation is responsible for the ownership, operation, and maintenance of all traffic signals located on state owned roads. Counties in New Jersey are responsible for the ownership, operation, and maintenance of all signals located on county roads***, *except in Camden County, where the municipalities own, operate, and maintain the traffic signals.* ***Traffic signals located on municipally owned roads are owned, operated, and maintained by the municipality***.[46]
New York	***In New York, the New York State Department of Transportation owns, maintains, and operates all traffic signals located on state highways***. *In fact, if a locally owned signal is close enough to an important state corridor, the state will assume ownership, maintenance, and operation over that signal. Generally, New York State law permits counties to own, maintain, and operate traffic signals located on county roads. All counties in New York utilize this law except for Albany County, which has deferred signal ownership, maintenance, and operation to the local level. State ownership, maintenance, and operation of signals have precedence at intersections with county or local roads.*[47]
Nevada	*The Nevada Department of Transportation does not own, maintain, or operate traffic signals****. The state funds and staffs the construction of signals. However, traffic signals in Nevada are owned, maintained, and operated by either a county or city depending upon the type of road ownership.***[48]
North Carolina	*There are 8000 state-owned signals throughout North Carolina. This includes state roads that traverse municipalities. State-owned signals outside city borders are operated and maintained by the NC Department of Transportation.* ***Signals on state roads that are within city limits are still owned and operated by the state, but maintained by the municipality; however any maintenance work by the municipality is reimbursed by the state.***

Exhibit 2.8: State Summaries – Traffic Signal Ownership

State	Summary
Ohio	***The Ohio Department of Transportation owns, maintains, and operates all traffic signals located on state or U.S. roads that are located outside of corporate limits.*** *Traffic signals located inside corporate limits are owned, maintained, and operated by the municipality regardless of the road type. Counties in Ohio have the responsibility of ownership, maintenance, and operation of those signals located in unincorporated areas but not on state or U.S. roads.* ***Moreover, state-owned signals that are in close proximity to major municipally-owned closed loop systems, remain under state ownership, however, the municipality assumes control over the maintenance and operations of those signals.***[49]
South Dakota	*Traffic signals located on state highways are owned, maintained, and operated by the state, unless the state highway traverses a city. In this instance, the state still retains ownership over the signals but the city maintains and operates the signals under a maintenance agreement. Traffic signals located on city owned streets are the sole responsibility of that city. Traffic signals located in rural county or unincorporated areas, are owned, maintained, and operated by the entity that applied for the signal permit.*[50]
Tennessee	*In Tennessee, the state does not own, maintain, or operate any traffic signals. By state law, cities or counties are responsible for the ownership, maintenance, and operation of all signals on every road in the state.* ***Interestingly, according to the Tennessee Department of Transportation, cities and counties in the state are clamoring to obtain traffic signals so that they can exert local control over the road system.***[51]
Texas	***The state owns, operates and maintains all signals on state roads that traverse cities less than 50,000, while cities over 50,000 can maintain and own those signals pending agreement by Texas DOT***. *Counties and municipalities operate signals within their borders that are not state roads.*
West Virginia	*Signals outside municipalities are owned and operated by WVDOT. Cities own signals on non-state roads within their borders.* ***The state also owns but does not maintain signals on state highways within cities, but the cities usually ask WVDOT to maintain the signals as well.***
Wisconsin	*Signals in the state are either on state highway trunk roads or on local roads.* ***Signals on local roads are owned, operated and maintained by the local municipality. Signals on state trunk roads are owned, operated and maintained by the eight DOT districts***. *State trunk roads that intersect local roads can be operated and maintained by the city if they so choose. All told, there are about 900 signals owned by the state.*

2.4. SUMMARY OF BACKGROUND AND PERSPECTIVE

Pennsylvania has one of the largest of state owned road systems in the country. By contrast, the state does not own, operate, or maintain traffic signals. Municipalities must fund and care for their traffic signals with oversight from PennDOT. In most other states, there exists a tiered system of traffic signal ownership, maintenance, and operation in which, typically, the owner of the road owns the signals. Moreover, Pennsylvania traffic signals are clustered in heavily populated areas, many in and around Pittsburgh and Philadelphia; however, more than a thousand municipalities own at least one signal.

It is widely acknowledged that traffic congestion is a significant economic and quality of life concern. One study conducted in Philadelphia, found congestion impact is most prevalent in Center City and around heavily industrialized areas. As 5% of congestion delay hours can be attributed to traffic signals, Pennsylvania may be able to improve its economic vitality of its larger metropolitan areas by addressing the concerns highlighted in this study as part of Phase II.

PHASE I – GENERAL ASSESSMENT

3. OUTREACH

As part of the study, outreach was conducted through a variety of methods.

- Participated in a roundtable discussion in Philadelphia area hosted by the Mid-Atlantic Section on the Institute of Transportation Engineers (MASITE) and the Intelligent Transportation Society of Pennsylvania (ITSPA)
- Hosted a workshop involving 40+ stakeholders from both the public and private sectors
- Distributed a survey (**results in Appendix B**) to interested individuals to gain additional insights.

3.1. MASITE AND ITSPA ROUNDTABLE MEETING ON TRAFFIC SIGNAL SYSTEMS

On June 30th, MASITE and ITSPA hosted a roundtable meeting on traffic signal systems in eastern Pennsylvania. There were 80+ attendees from the public and private sectors in attendance. Roundtable participants included:

- Carmine Fiscina – Federal Highway Administration
- Charles (Chick) Dougherty – Delaware Valley Regional Planning Commission
- Ashwin Patel – PennDOT Engineering District 6-0 Traffic Unit
- Charlie Denny – City of Philadelphia Streets Department Traffic Unit
- Joseph Ferguson – Signal Service, Inc.
- Harry Orlando – McMahon Associates
- Brian Keaveney - Pennoni Associates

Some of the issues discussed included:

- The need for a regional approach to signal systems and interjurisdictional issues.
- The industry has not done a good job studying and documenting the benefits of signal systems because the focus of most projects is implementation and not evaluating the results.
- Advanced signal systems and other technologies are not fully utilized.
- Signal timings are not refined and updated as they should be.
- The needs of pedestrians should be considered when evaluating signal systems.
- Should there be standard equipment? Should it be software or hardware based? Are we limiting ourselves by choosing standard equipment?
- Should the permit process require retiming periodically?

Bob Taylor and Mark Metil of Gannett Fleming described the TAC Study and distributed a survey to interested parties.

3.2. JULY 1ST TRAFFIC SIGNAL SYSTEMS WORKSHOP

As required by Phase I, Task 2 of the scope of work, a structured issues identification stakeholder workshop was held on July 1, 2004 at the Camp Hill Office of Gannett Fleming, Inc. to gain insight into traffic signal system issues throughout the Commonwealth. The main objectives of this workshop were to identify key categories and evaluation criteria, and to identify overarching issues pertaining to traffic signal systems and how they affect traffic congestion in the Commonwealth.

3.2.1. Attendees

Invitations for the workshop were sent to all PennDOT districts, PennDOT Central Office, select MPO/RPOs, select municipalities, consultant companies, signal operation and maintenance companies, and other organizations that would have an interest in traffic signal systems in the Commonwealth.

Over forty attendees participated in the July 1st Workshop. Those present represented:

- PennDOT
- MPO/RPOs
- Municipalities
- Consultant community
- Maintenance contractors
- Transit community leaders.

A detailed list of attendees is located in **Appendix A** of this report. The attendees provided valuable insight and identified nearly 150 issues during a brainstorming session.

3.2.2. Workshop Approach/ Summary

The workshop was organized into three blocks:

Block
Block 1: Categories and Issues
Block 2: Evaluation Criteria and Ranking

Block 3: Targeted Issues and Actions

The goal of Block 1 was to identify key issues and categories associated with traffic signal systems; in particular, how they can impact or are impacted by congestion.

The consultant team provided participants with 12 categories for issue classification as a starting point and the stakeholders recommended two additional issue categories. The final categories include:

- ❑ Policy and Planning
- ❑ Funding
- ❑ Jurisdictional and Ownership
- ❑ Enforcement
- ❑ Procurement
- ❑ Technology
- ❑ Engineering & Construction
- ❑ Operations and Management/Efficiency
- ❑ Maintenance
- ❑ Safety
- ❑ Training and Expertise
- ❑ Public Education
- ❑ Legal/Liability
- ❑ Legislative.

The second part of Block 1 included the brainstorming of more than 150 issues. These are discussed in the next section of this report.

In the second block of the workshop, participants were organized into four breakout groups and asked to rank the top 10-15 issues in order of importance. As part of this ranking, they were also asked to identify research topics or innovative ideas.

The breakout groups identified nine high level overlapping issues which will be discussed further in **Section 4.4**.

- Funding
- Holistic approach to signal systems
- Training
- Operational monitoring and audits
- PennDOT authority
- Embrace technology
- Access management and land use
- Maintenance and operations guidelines
- Ownership.

The third block of the workshop highlighted the top issues and identified follow-up actions, ideas and potential barriers. This portion of the workshop was used to report back the breakout group's top ranked issues and to identify ideas that were generated by each of the groups.

The workshop was positively received. Many participants expressed gratitude for the opportunity to discuss issues associated with traffic signal systems. Other participants commented that the workshop provided a good forum to share experiences and discuss ideas.

Participants looked forward to short-term solutions for smaller problems as well as establishing a comprehensive vision regarding the Commonwealth's traffic signal systems for the future. The purpose for holding the workshop – issues identification – was achieved.

3.3. DISTRICT TRAFFIC ENGINEERS MEETING

On October 14th, 2004 at PennDOT Engineering District 9-0, the District Traffic Engineers were briefed on the TAC study and its status. The briefing included a summary of work performed up to that point as well as a discussion of the core themes that emerged out of the workshop as well as potential solutions from PennDOT's perspective. The meeting included a discussion of the best practices within each districts such as asset management, operational oversight and training.

3.4. SURVEY AND OTHER FEEDBACK

Throughout the study, stakeholders who were unable to participate at the July 1st workshop were engaged through a general use survey. Respondents included:

- Charles Oyler, Upper Dublin Township
- Douglous Cleland, Lower Merion Township
- Joe Rosadi, West Whiteland Township
- Sharon Lynn, West Goshen Township
- Terry Grove, Grove Miller Engineering.

Detailed responses to the survey are included in **Appendix B**. Key overlapping themes from the survey are detailed below (**see Exhibit 3.1**). It should be noted that not all the issues listed below are consistent with the workshop feedback. In some cases, the responses contradict the workshop feedback and therefore the recommendations of this study.

Exhibit 3.1: Survey Feedback

Category	Issue
Policy and Planning	Need to streamline the signal modification process between the municipality and PennDOT.
	Should PennDOT own and maintain all signals or at least those on state roads?
Funding	Need dedicated funding to operate and maintain signal systems.
	Funding should come from Liquid Fuels TAx.
Jurisdictional and Ownership	Need to address signal systems across municipal boundaries or even at a regional level.
Technology	Need to improve the process of accepting new technologies.
Engineering & Construction	Need flexible standards (foundations and utilities) so that field issues can be addressed.
	Need to develop common specifications.
Operations and Management/ Efficiency	Need an asset management tool to track maintenance and operations.
	Need to better utilize closed-loop systems.
	Should PennDOT maintain and operate signals?
	Should we define typical operational parameters for types of systems?
	Should there be criteria developed for traffic responsive systems?
Safety	Need to integrate more preemption systems.
Training and Expertise	Need programs to educate municipalities about signal systems.
Public Education	Need methods to inform public about signals and new technologies other than adding signs.
	If PennDOT owned signals, then citizen issues can be more directly addressed.

4. ISSUE DEVELOPMENT

4.1. ISSUES IDENTIFICATION AND CATEGORIZATION

As discussed in the previous section, the workshop yielded more than 150 issues related to traffic signal systems. These issues were in addition to, but often overlapped with, issues identified in survey results and issues identified by Task Force members. The master issues list is included in **Appendix C.**

4.2. DEVELOPMENT OF REVIEW CRITERIA

As discussed, the study objectives are to:

- ❑ Produce an evaluation of relevant issues associated with the policies and practices of traffic signal systems throughout the Commonwealth.
- ❑ Identify alternatives to reduce congestion.
- ❑ Make feasible recommendations for ways traffic signal systems might be better planned, deployed, and managed to improve safety and congestion management.

To gauge the merits of each issue and in order to assess possible solutions, the Study Team with input from the Task Force and workshop participants identified the following criteria (**see Exhibit 4.1**) for issues evaluation.

Exhibit 4.1: Criteria and Considerations for Issue Evaluation

Criteria	Considerations
Network Delay and Travel Time	These are the fundamental considerations in evaluating signal systems. Network delay considers how much delay all motorists experience when traveling though the system. The travel time is the actual time it takes to travel the system.
Intersection Operations	Intersection operations considers delay and Level of Service. In some cases, the needs of an individual intersection do not yield the best benefit for the entire system. For example, in some systems, it may be appropriate to favor the mainline versus balancing the demands and operations of all approaches.
Crash Reduction	Safety impacts operations through non-recurring congestion. If intersections can be made safer, less time is lost due to incidents and related traffic impacts.
Financial Savings	If a solution yields a financial savings, those resources can be used to address congestion elsewhere. Financial savings may also relate to public benefits of time savings.
Intermodalism	By encouraging other modes of travel (pedestrian and transit) through design of intersections, we can reduce the effective demand on our roadway system.
Public Perception	In many cases, congestion is a perceived problem. Many motorists can accept the physical limitations of the roadway infrastructure, but react negatively when easy fixes are not implemented such as properly operating signals.
Practical Feasibility	In all cases, solutions need to be practical and feasible. If long-term changes need to be made or funding is required, then these things need to be identified.
Asset Management	This was not included in the original criteria list, but was added due to its importance. In order to "better plan, deploy, and manage" our signal systems, we need to better manage them as an asset.

It is important to note that although reduction of congestion is the underlying theme, other criteria should be considered to offer benefits to the motorists and system owners. In many cases, these criteria directly impact congestion.

It is also important to note that in many cases the congestion related benefit is site specific. For example, an isolated rural system or a highly congested urban system may yield less delay reduction than a moderately congested system that is not operated efficiently.

4.3. Issues Prioritization

Each workshop group was asked to prioritize the key issues associated with signal systems. **Exhibit 4.2** illustrates the ranked issues by group and identifies the overlap between groups: i.e., issues prioritized by more than one group.

Exhibit 4.2: Issues Prioritization by Group

#	Issue	Issue Overlap			
Group 1		***Group 1***	***Group 2***	***Group 3***	***Group 4***
1	Funding - Liquid fuels formula updating to address operations. A dedicated funding source for signals operation and maintenance.		Y	Y	Y
2	Holistic approach– A corridor view/ approach is needed and a methodology/ policy need to be established to address signal systems that cross jurisdictional boundaries. Incident/event management and detour coordination should be considered in corridor evaluations.		Y	Y	Y
3	Training - A comprehensive approach to address training, certification, inspection and education for all parties.		Y	Y	Y
Group 2		***Group 1***	***Group 2***	***Group 3***	***Group 4***
1	Operational control and monitoring				
2	Dedicated funding source	Y		Y	Y
3	Holistic approach	Y		Y	Y
4	Liquid fuels – Need to explore alternatives	Y		Y	Y
5	Electrical and IT issues not covered by civil engineering				
6	Ownership- what are other states doing				Y
7	Access management and land use- what are the benefits			Y	
8	Municipalities can't try certain technologies because of PennDOT standards			Y	
9	Monitor and follow-up of signal systems (timing adjustments)			Y	Y
10	IMSA Training	Y		Y	Y
11	PennDOT authority to enforce (or authority is not enforced)			Y	Y

Exhibit 4.2: Issues Prioritization by Group (Continued)

#	Issue	Issue Overlap			
Group 3		*Group 1*	*Group 2*	*Group 3*	*Group 4*
1	MPO/RPO funding of maintenance and operations				
2	Regional priority of corridors for operations of signal systems	Y	Y		Y
3	Municipal education regarding maintenance and operations (audits)		Y		Y
4	Lack of PennDOT authority or failure to enforce (signal upgrades or maintenance)		Y		Y
5	Update Publication 191 guidelines (maintenance and operations)				Y
6	Highways should be "operated"(not just constructed and maintained)	Y	Y		Y
7	Enforcement of red light running				
8	Training (design, inspection and operation)	Y	Y		Y
9	Cross-jurisdictional operations				
10	Government fragmentation (including counties)	Y	Y		Y
11	Embrace technology (based on expertise and needs)		Y		
12	Streamline permit process				
13	Access management and land use		Y		
14	Standardize hardware and software so that each can be integrated/compatible				
15	Liquid fuels formula is outdated	Y	Y		Y
16	Space on utility poles for conduits				
17	Who should operate signal systems?	Y	Y		Y
Group 4		*Group 1*	*Group 2*	*Group 3*	*Group 4*
1	Ownership		Y		
2	Certification - use IMSA as a resource	Y	Y	Y	
3	Dedicated funding source	Y	Y	Y	
4	PennDOT authority to enforce		Y	Y	
5	Operational audits		Y	Y	
6	Liquid fuels	Y	Y	Y	
7	Emergency preemption				
8	Traffic management centers (will they exist?)				
9	Separation in funding	Y	Y	Y	
10	Unfunded local mandate				
11	Training for technology	Y	Y	Y	
12	Who should operate, control and monitor?	Y	Y	Y	
13	Periodic reviews (6 months per Pub 191) is not often enough			Y	
14	Maintenance funds through MPO/RPO's	Y	Y	Y	
15	Highways not "operated"	Y	Y	Y	

Nine issues or "themes" were identified that overlapped multiple groups (**see Exhibit 4.3**). Each theme had a basic relationship to the underlying goal to reduce congestion.

Exhibit 4.3: Core Themes Identified at July 1st Workshop

Theme	Considerations	Basic Relationship to Congestion (Operations)
Funding	Liquid fuels formula needs to be updated to address signal operations. A dedicated funding source is needed for signal operation and maintenance. Also, funding at the planning organization level should be considered for operations and maintenance. Overall, it was felt that operations and maintenance is under funded since the operational implications are not appreciated and the importance is placed (understandably) on high cost, high importance infrastructure elements such as bridges or high volume roadways.	➢ Operations are a secondary concern because funding is used to keep the system running (i.e., more "bricks and mortar" improvements.)
Holistic approach to signal systems	A corridor view/ approach is needed and a methodology/ policy needs to be established to address signal systems that cross jurisdictional boundaries. The basic policies and practices for maintenance versus operational control need to be considered. Should there be a tiered approach? Should one entity maintain and another operate signals? Should there be operational (volume) thresholds or other scenarios where the state, county or MPO/RPO assumes operational jurisdiction? Incident/ event management and detour coordination needs to be considered in corridor evaluations as well as the integration of advanced signal systems into management centers to utilize this technology to its fullest.	➢ Operations are impacted because there is a disconnect between municipalities and no regional evaluation/oversight of corridors.
Training	A comprehensive approach is needed to address training, certification, inspection, and education for all parties to ensure there is expertise to design, construct, operate and maintain traffic signals. The training needs to bridge the gap between design, construction and operations, as well as the gap between civil engineering, IT, electrical, and other disciplines involved in signal systems.	➢ Lack of expertise in timing and system development, impacts operations ➢ Lack of utilization of systems potential (impacting operations) due to lack of expertise.
Operational monitoring and audits	Systems can not be designed and built then left unchanged or not maintained. Policies and practices are needed for the types of timing plans and methods to be implemented, the fine-tuning process, the daily oversight, and periodic reevaluation.	➢ Operations are impacted by "out-of-date" timing plans ➢ Operations are impacted as timings are implemented but not later fine-tuned ➢ Operations are impacted because timing plans do not often reflect weekend and/or special events.
PennDOT authority	PennDOT should review the sufficiency of its operational and maintenance authority, garner support, and educate partners about the importance of proper maintenance and operations. When necessary, PennDOT should have some mechanism to enforce operational and maintenance requirements. In lieu of that, current administrative requirements (such as timing revisions) should be reviewed to identify where processes can be streamlined to the benefit of all parties.	➢ It is difficult for PennDOT to address municipal failures to adequately modernize, operate or maintain their signals.
Embrace technology	Since PennDOT does not own signal systems, it is difficult to test new technology. At the same time, municipalities express frustration in the delay in adopting new technologies. Mechanisms to streamline the testing – evaluation – deployment process and to develop evaluation partnerships should be explored. Furthermore, new technology requires training programs to ensure it is properly used.	➢ Operational benefits are not fully realized due to implementation delay of new technologies.

Exhibit 4.3: Core Themes Identified at July 1st Workshop

Theme	Considerations	Basic Relationship to Congestion (Operations)
Access management and land use	The policies and practices of access management and land use management should be explored as they relate to the operations of signal systems should be explored.	➢ Operations are often impacted by land use practices and are often a secondary development consideration. ➢ Access management strategies may improve operations through consolidation of access and spacing guidelines.
Maintenance and operations guidelines	The current guidelines for maintenance and operations are outdated and should be reviewed. Particularly, the distinctions between maintenance and operations should be clarified. Also, clarify that basic signal maintenance does not mean it is operating to its full potential.	➢ Signals are not properly maintained and operated partially due to a lack of guidance, thus impacting operations.
Ownership	This is related to "holistic" approach, but not entirely. Some view signals as an "unfunded local mandate." Some want PennDOT to take ownership. Others do not. Views on ownership relate to funding, but practices in other states will be reviewed to determine alternate ownership strategies. Maybe, municipalities that own a small number of signals should band together with other municipalities into a meaningful group of signals to facilitate operations and maintenance? Perhaps there should be a tiered or staggered approach? Perhaps MPO/RPO's, counties or PennDOT should assume control for critical arterials?	➢ Some municipalities are not equipped (funding, staffing, and expertise) to maintain and operate a signals.

4.4. 21ST CENTURY VISION

The results of the July 1st workshop were presented to the TAC Task Force on July 8, 2004. The Task Force agreed with most of the issues and underlying themes and provided additional guidance.

It was agreed that the overlapping themes should be used to identify a "Vision for the Future." The vision statement was intended to :

- ❑ Help guide the Study Team in assessing and researching the key issues for Phase I and Phase II.
- ❑ Establish a long-term vision, so that short-, mid- and long-term solutions, as well as pilot projects, can be established that support and do not conflict with the overall vision.

The backbone for the issue selection is a general vision for a more holistic approach to traffic signals for the 21st Century. The holistic approach includes six major categories of integrated strategies. These are shown as boxes in the following graphic, **Exhibit 4.4**. Under each category, the specific issues are identified for further research. These were selected from the July 1, 2004 workshop, the input of the TAC on July 8th, and the consultant staff

Exhibit 4.4: 21st Century Vision

The vision of **Pennsylvania's 21st Century traffic signal systems** includes a ***holistic approach*** to the operations and maintenance of signal systems driven by renewed ***policies and practices*** that identify ***institutional responsibilities and accountability***. In addition to being adequately maintained, the systems will be ***efficiently operated*** so that they properly respond to traffic demands including incidents, homeland security needs and special events. The systems will be planned, designed, constructed, maintained and operated by an ***effectively trained*** interdisciplinary staff and utilize a level of ***technology*** appropriate for the signal systems and the staff supporting them. ***Education*** of the importance and operations of signal systems to stakeholders and the public would elevate awareness.

Holistic Approach

- Statewide interconnection
- Regional interconnection
- Interjurisdictional interconnection
- Corridor wide systems
- Integrate signal systems with other technologies such as traffic management centers (TMCs)

Planning / Policy Driven

- Tiered/ shared approach to maintenance and operations
- Regional prominence/focus
- Interjurisdictional cooperation
- Consistency and flexibility across Districts
- Land use / access management/ signal system policies coordinated
- Legislative actions as needed
- Privatization approaches as effective

Institutional Responsibilities / Accountability

- Better maintenance and operations practices
- Rational approach to state / local responsibilities
- Discipline integration
- Ownership optimized
- Oversight defined and enforced
- Managed asset

Efficient Operations

- Streamline operational adjustment (timing) procedures
- Daily oversight / fine tuning
- Operational audits performed
- Regular inspections
- Incident response/ homeland security/ special event coordination
- Responsive to demands
- Performance measures in place
- Standards / management controls enforced
- Traffic Integration Management Systems (TIMS) realized

Effective Training / Education

- Technical training
- Interdisciplinary cross-training
- Public education regarding signals
- Public hotline for problem identification

Effective Use of Technology

- Testing and research programs
- Cooperative research
- Before and after studies (pre-test/post-test)
- Application of research
- Best practices researched / employed

Improved Funding Strategies

- Dedicated funding in place
- Reviewed funding formulas
- MPO/RPO funding for maintenance and operations
- Operations funding available
- Impact fees assessments utilized
- Public/ private partnerships employed
- Incentives for innovation
- Shared responsibility

5. Research and Benchmarking

5.1. Key Resources

Researching and benchmarking involved a multifaceted approach.

More than 80 resources /publications were researched for their applicability to this study.

- First, the existing background and perspective within Pennsylvania were investigated along with existing policies and practices.
- Next, handbooks and engineering guides were reviewed for key information.
- The web and key sites were researched for related information, and
- Finally, case studies were identified and researched.

A summary of each publication/resource is contained in **Appendix D**.

5.1.1. Pennsylvania Resources and Studies

There is a variety of engineering and maintenance-related traffic signal system guidance but there has been limited research related to the Pennsylvania policies and practices. The Southwestern Pennsylvania Regional Planning Commission (SPC) conducted the most significant research regarding policies and practices, but focused primarily on the 10-county Pittsburgh region.

5.1.2. Handbooks and Guidelines

Most handbooks and guidelines address engineering and maintenance issues associated with signal systems. Some have limited guidance on policies and practices, as well as ownership and funding.

5.1.3. Articles and Web Resources

The internet provides access to numerous additional articles and documents related to signal systems. Many of the articles document real world examples. Some are subjective articles by industry leaders. FHWA published a Cross-Jurisdictional Signal Coordination Case Studies which was useful in relation to this study. Also, the United States General Accounting Office conducted a study documenting the benefits of signal systems and the problems with implementation.

5.1.4. Case Studies

More than twenty case studies, not associated with other research, were evaluated. These studies are valuable in assessing potential solutions and identifying lessons learned.

5.1.5. Anticipated Resources

Throughout Phase I, several other documents were identified. Some of these studies and documents were in development at the time of this project. The Study Team acquired and followed-up as needed to include the most current research.

5.1.6. Telephone Interviews

Telephone interview with Pam Crenshaw, FHWA Program Manager, on July 23, 2004.

In order to gauge the national perspective, the Study Team contacted FHWA Arterial Operations Program Manager, Pam Crenshaw. Discussion centered on anticipated resources, many of which are included on the FHWA Current Program Activities Website or shown in Anticipated Resources of this document. Other discussion included the ability to use safety funds for traffic signal projects, as exemplified in an Upstate New York project. These activities are focused around stopping red light running. Case study examples of particular note were Oakland County, MI and Denver Regional Council of Governments (DRCOG).

5.2. Summary of Best and Innovative Practices

A variety of practices discovered in Phase I research is listed below, organized by the TAC study categories. This was used by the Task Force to consider potential PA directions.

Exhibit 5.1: Summary of Best and Innovative Practices

Category	General Practice	Brief Summary of Practice	State	Reference
Education	Public education of signals	Seattle's Smart Trek Program used websites and cable television to reach the public	Washington	Jensen, M. et al. Metropolitan Model Deployment Initiative Seattle Evaluation Report: Final Draft. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@3301!.pdf.
Education	Public hotline of problems	Website available for the public, but also used to retime traffic signals	North Carolina	ITS America. NCDOT Requests Input On Web Site Design. March 2004. http://www.itsa.org/ITSNEWS.NSF/0/08072ef01e0d0d7985256e5500536ac2?OpenDocument.
Education	Technical Training	Traffic Signal Summer Camp for engineering students	Idaho	National Institute for Advanced Transportation Technology. Traffic Signal Summer Camp. November 2001. http://ntl.bts.gov/data/KLK205.pdf.
Education	Technical Training	Consortium for ITS Training and Education (CITE) Traffic Signal Timing	Multiple	ITS America. Another Offering of CITE's VERY Successful "Blended" Traffic Signal Timing Course. January 20, 2004. http://www.itsa.org/ITSNEWS.NSF/0/0aca0289f4642c1a85256e2100717884?OpenDocument.
Funding	Dedicated funding in place	Funding increases from the State Government	Georgia	ITS America. Georgia Governor Announces "Fast Forward Transportation" Program. April 2004. http://www.itsa.org/ITSNEWS.NSF/0/c7d6a919d46ebfe685256e770008b8e3?OpenDocument.
Funding	MPO/RPO funding for maintenance and operations	Denver Regional Council of Governments (DRCOG) control of timing plans for STSIP	Colorado	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.
Funding	Public/private partnerships employed	Public Private Partnership to combine financial and staff resources, expertise, technology, management strategies, and infrastructure.	Minnesota	Minnesota Department of Transportation. Integrated Corridor Traffic Management. April 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9xb01!.pdf.

Exhibit 5.1: Summary of Best and Innovative Practices

Category	General Practice	Brief Summary of Practice	State	Reference
Funding	Shared Responsibility	LVACTS funding formula based on signal ownership	Nevada	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.
Funding	Shared Responsibility	TranStar Executive committee system of splitting funding by use	Texas	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.
Holistic	Corridor wide systems	Corridor-wide cooperation under State DOT guidance	Minnesota	Minnesota Department of Transportation. Integrated Corridor Traffic Management. April 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9xb01!.pdf.
Holistic	Integrate signal systems with other technologies such as traffic management centers (TMCs)	Tucson Traffic Control Center combines 7 agencies' signals	Arizona	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
Holistic	Integrate signal systems with other technologies such as traffic management centers (TMCs)	Information Exchange Network (IEN) to coordinate between Traffic Control Centers (TCS)	California	ITS America. LA County Shares Signals Online. July 2002. http://www.itsa.org/mn.nsf/0/e077abcf982e1d1b85256bdf006f4308?OpenDocument.
Holistic	Integrate signal systems with other technologies such as traffic management centers (TMCs)	TCC (Transportation Control Center) controlled on the County Level	Georgia	ITS America. Georgia ATMS Recognized for Excellence. February 1, 2000. http://www.itsa.org/itsnews.nsf/0/8a9ceab75f252a7785256879006826 1f?OpenDocument.
Holistic	Integrate signal systems with other technologies such as traffic management centers (TMCs)	TranStar Transportation Management Center is a regionwide center.	Texas	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.
Holistic	Interjurisdictional interconnection	Interconnection of Advanced Traffic Management Systems (ATMS) using National Transportation Communications ITS Protocol (NTCIP) between cities	Arizona	City of Phoenix. Successful ATMS/NTCIP Center To Field Integration In Phoenix And Lakewood. http://www.ntcip.com/new/PR_Phoenix_ATMS_0301.pdf.
Holistic	Interjurisdictional interconnection	Cross-Jurisdictional Signal Coordination among 7 agencies with the City of Tucson as the lead	Arizona	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
Holistic	Interjurisdictional interconnection	Cross-Jurisdictional Signal Coordination case studies of several corridors in Phoenix area	Arizona	FHWA. Cross-Jurisdictional Signal Coordination in Phoenix and Seattle. http://www.nawgits.com/jpo/lib/13222.pdf.

Exhibit 5.1: Summary of Best and Innovative Practices

Category	General Practice	Brief Summary of Practice	State	Reference
Holistic	Interjurisdictional interconnection	Cross-Jurisdictional Signal Coordination of 4 jurisdictions with the regional MPO/RPO as the lead	Colorado	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
Holistic	Interjurisdictional interconnection	Cross-Jurisdictional Signal Coordination among 3 agencies with no lead agency	Maryland	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
Holistic	Interjurisdictional interconnection	Cross-Jurisdictional Signal Coordination among 3 agencies with Monroe County as the lead agency in a formalized agreement (MOU).	New York	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
Holistic	Interjurisdictional interconnection	Philadelphia region example of an informal corridor wide agreement between 3 municipalities with the City of Philadelphia as the lead.	Pennsylvania	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
Holistic	Interjurisdictional interconnection	Detailed Cross-Jurisdictional Signal Coordination study with emphasis on emergency preemption.	Texas	FHWA. San Antonio's Medical Center Corridor: Lessons Learned From the Metropolitan Model Deployment Initiative. http://www.nawgits.com/jpo/lib/13220.pdf.
Holistic	Regional interconnection	Denver Regional Traffic Signal Improvement Program (STSIP) with MPO/RPO at the lead.	Colorado	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.
Holistic	Regional interconnection	Las Vegas Area Computer Traffic System (LVACTS) at a separate location with separate staff.	Nevada	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.
Holistic	Statewide interconnection	Statewide contracting for ATS systems.	Arizona	ITS America. Siemens to Install Statewide Traffic Signal System. February 2002. http://www.itsa.org/itsnews.nsf/0/a864c8f68174a2e985256b5d007fc87b?OpenDocument.
Institutional	Better maintenance and operations practices	Maryland State Highway Authority (MDSHA) communications link to test detector failures.	Maryland	TRB. Traffic Signal Control Systems Maintenance Management Practices. 1997. http://trb.org/news/blurb_detail.asp?id=3312
Institutional	Better maintenance and operations practices	Statewide computerized Maintenance Management System.	Minnesota	TRB. Traffic Signal Control Systems Maintenance Management Practices. 1997. http://trb.org/news/blurb_detail.asp?id=3312
Institutional	Discipline integration	TranStar transportation and emergency management personnel working together.	Texas	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.

Exhibit 5.1: Summary of Best and Innovative Practices

Category	General Practice	Brief Summary of Practice	State	Reference
Institutional	Oversight defined and enforced	AZtec Technical Oversight Committee model.	Arizona	FHWA. Cross-Jurisdictional Signal Coordination in Phoenix and Seattle. http://www.nawgits.com/jpo/lib/13222.pdf.
Operations	Daily oversight / fine tuning	Website available for the public, but also used to retime traffic signals	North Carolina	ITS America. NCDOT Requests Input On Web Site Design. March 2004. http://www.itsa.org/ITSNEWS.NSF/0/08072ef01e0d0d7985256e5500536ac2?OpenDocument.
Operations	Daily oversight / fine tuning	TranStar Regional Computerized Traffic Signal System (RTCSS) oversight by staff to deal with emergency preemption and transit priority	Texas	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.
Operations	Incident response / homeland security / special event coordination	CHART (Chesapeake Highway Advisories Routing Traffic) system of incident response.	Maryland	Maryland Department of Transportation. Charting your course : Maryland CHART program. http://www.itsdocs.fhwa.dot.gov//JPODOCS/BROCHURE/1Z901!.PDF.
Operations	Incident response / homeland security / special event coordination	Traffic and Incident Management Program (TIMS) system of incident response.	Pennsylvania	FHWA. Incident Management Successful Practices/ Improving Mobility and Saving Lives. April 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/8v001!.pdf.
Operations	Incident response / homeland security / special event coordination	TransGuide freeway and incident management system	Texas	FHWA. San Antonio's Medical Center Corridor: Lessons Learned From the Metropolitan Model Deployment Initiative. http://www.nawgits.com/jpo/lib/13220.pdf.
Operations	Responsive to demand	Smart Signals ATMS system highly publicized	Florida	King, Dale M. Smart Signals. Boca Raton News. May 26, 2004. http://www.bocaratonnews.com/index.php?src=news&prid=8426&category=LOCAL%20NEWS&PHPSESSID=888c635c174e11df5f65a6e0f521b457.
Operations	Responsive to demand	Guidelines for Conducting a Traffic Signal Warrant Analysis	Texas	Texas Transportation Institute, Traffic Signal Guidelines Get A "Green Light." 1999. http://tti.tamu.edu/researcher/newsletter.asp?vol=35&issue=4&article=0
Operations	Responsive to demand	Smart Signals system as part of statewide improvements.	Virginia	ITS America. VDOT Using Information Technology to Keep Virginia Moving. May 1999. http://www.itsa.org/itsnews.nsf/0/d010544dbacfe26e8525676a00684720?OpenDocument.
Policy	Interjurisdictional cooperation	Pima Association of Governments Transportation Planning Division (PAGTPD) organization with the City of Tucson at the lead	Arizona	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.

Exhibit 5.1: Summary of Best and Innovative Practices

Category	General Practice	Brief Summary of Practice	State	Reference
Policy	Interjurisdictional cooperation	Informal agreements between Washington, DC, Montgomery County, MD, and Maryland State Highway Administration (MdSHA)	Maryland	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
Policy	Interjurisdictional cooperation	LVACTS autonomy of liability and maintenance	Nevada	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.
Policy	Interjurisdictional cooperation	Informal agreements between Philadelphia, Upper Darby, and Springfield	Pennsylvania	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
Policy	Interjurisdictional cooperation	TranStar local autonomy with communication	Texas	Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/feasibility-section2.pdf.
Policy	Pubic / private partnerships	Utilities aid with LED replacement	Maine	AASHTO. Maine's Statewide Traffic Signal Bulb-to-LED Replacement Program. 2002. www.transportation.org/aashto/success.nsf/allpages/2003-14maine.
Policy	Tiered / shared approach to maintenance and operations	Formalized agreement (MOU) of maintenance between Monroe County, NY, City of Rochester, and New York State Department of Transportation (NYSDOT)	New York	FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
Technology	Application of research	ATMS (Advanced Traffic Management Systems)	Georgia	ITS America. Georgia ATMS Recognized for Excellence. February 1, 2000. http://www.itsa.org/itsnews.nsf/0/8a9ceab75f252a77852568790068261f?OpenDocument.
Technology	Before and after studies	Before and after studies of traffic signal improvements	Arizona	FHWA. Cross-Jurisdictional Signal Coordination in Phoenix and Seattle. http://www.nawgits.com/jpo/lib/13222.pdf.
Technology	Best practices researched / employed	Early example and extensive study of ATS in the form of Sydney Coordinated Adaptive Traffic System (SCATS)	Michigan	Road Commission for Oakland County, Michigan. Lifecycle Costs Case Study Summary. www.itsa.org/subject.nsf/Files/CaseStudyFAST-TRAC/$file/CaseStudyFAST-TRAC.doc.
Technology	Best practices researched / employed	Adaptive Urban Signal Control and Integration (AUSCI) in a CBD with multiple technologies	Minnesota	Minnesota Department of Transportation. Adaptive Urban Signal Control and Integration. October, 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@@n01!.pdf.
Technology	Public/private partnerships employed	Example of Sydney Coordinated Adaptive Traffic System (SCATS) across jurisdictional boundaries	Minnesota	Minnesota Department of Transportation. Integrated Corridor Traffic Management. April 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9xb01!.pdf.

5.3. PENNDOT BEST PRACTICES

Each Engineering District and the Bureau of Highway Safety and Traffic Engineering (BHSTE) has their own unique operating procedures with regard to traffic signal systems. Each District was interviewed to identify best practices regarding staffing, training, maintenance and operations, as well as other practices related to the key issues. While each district provides unique insight, it should be noted Districts 5, 6, 8 and 11 oversee more than 1,200 signals each while Districts 2, 3 and 10 oversee less than 300 signals each.

General findings from these interviews are noted below:

- Most Districts have few people designated to work with signals and signal systems, usually no more than 5 or 6 staff dedicated to traffic signals. In many cases, they have other responsibilities in addition to traffic signals.
- Training venues primarily include software training and coursework. Popular training tools included Synchro, Highway Capacity Software, and the Northwestern University Traffic Signal Workshops.
- PennDOT's Traffic Resources Education and Computing Support (TRECS) group meets quarterly to assess software and hardware needs including training as well as to discuss publication needs.
- For signal timing modification procedures, municipalities contact the district office to request modifications. Larger communities often have the capability to do the required analyses based of changes in traffic flow, and will submit their findings to the district office for permit approval. Smaller communities usually rely on the district to do the analysis.
- In the case of developer-requested modifications, there are more requirements. The developer is frequently required to undertake all necessary analysis. In District 11, it is strongly recommended that the municipality where the new/upgraded signal is requested supports with the development project before developers request modifications.
- In all cases, permits were not enforced in any legally binding way. Some district traffic engineers noted attempts to enforce permits by contacting communities that were not following the permit, but no other enforcement measures were possible.
- The provision of operational oversight is sporadic. Some districts reported at least informal oversight, acting primarily as advisors. However, most respondents indicated that their ability to provide meaningful oversight is limited by a lack of time.
- Most districts treat signals and signal systems in the same way. While District 6 has a systems permit that is different from individual signal permits, and District 4 is on the verge of a similar signals permit, they are the only two who specifically mentioned such permits.
- The use of asset management tools varies significantly. Most districts reported using no asset management tool whatsoever. Several districts have a database of signals,

but reported that it is not well maintained. Finally, District 6 uses an Access-based tool with a GIS interface.

- Nearly all respondents felt that advanced signal systems were not used to their fullest capabilities. Among the most frequently cited reasons were a lack of funding and a lack of multi-jurisdictional coordination.

- Both the Traffic Signal Enhancement Initiative (TSEI) and the Congested Corridor Improvement Program (CCIP) are valuable tools in congestion reduction. The goal of the TSEI is to reduce travel times and delay on specified signalized corridors. The TSEI focuses primarily on signal issues such as timing, operations, maintenance, and technology. The objective of the CCIP is to reduce delay by 20 percent on selected corridors. CCIP improvements are directed at activities such as roadway geometry, signal operations, access management, multimodal initiatives, intelligent transportation systems (ITS), traffic regulation techniques, transportation demand management (TDM) measures, and planning and zoning practices that are appropriate for a particular transportation corridor.

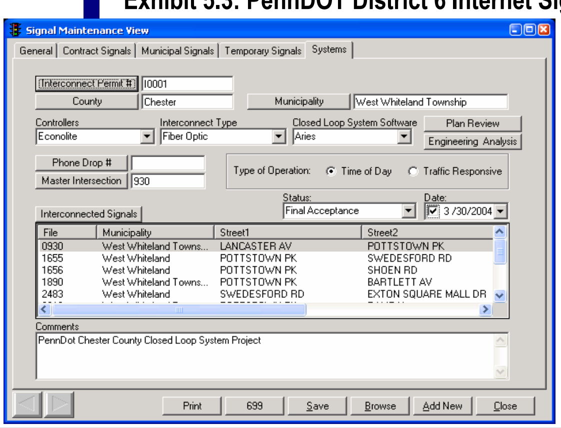
5.3.1. Engineering District 6-0

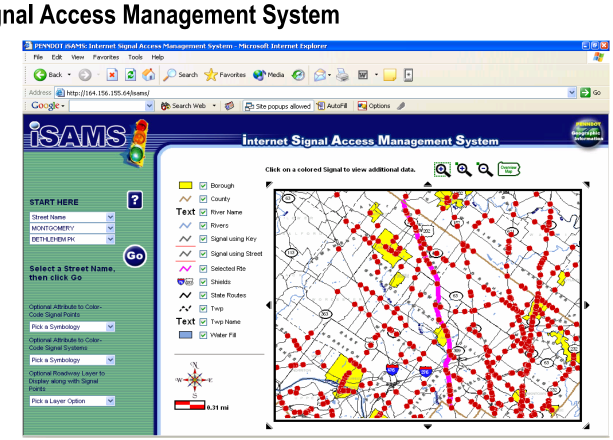
Engineering District 6 has undertaken several unique initiatives to better manage signal systems.

- In order to manage the interconnected traffic signals located throughout PennDOT District 6 (Bucks, Chester, Delaware, Montgomery, and Philadelphia counties), signal system plans are required from each system designer, such as a municipality, developer, or District 6 itself. The plans reflect both time of day and traffic responsive system data for 100 systems with signalized intersections. Manual traffic counts are conducted for each of the 100 permitted signalized systems to enable District 6 to enhance signal timings and coordination settings.

- In addition, District 6 maintains a database to retrieve information on signal systems District-wide (**see Exhibit 5.2 left**). In fact, District 6 interfaces this database with its GIS mapping software to optimally plan the location of traffic signals (**see Exhibit 5.3 right**). District 6 plans to upgrade its software to connect to PennDOT's GIS system in the future.

Exhibit 5.2: PennDOT District 6 Signal Maintenance Database
Exhibit 5.3: PennDOT District 6 Internet Signal Access Management System





5.4. PHASE I RESEARCH AND BENCHMARKING SUMMARY

Phase I included a significant research and benchmarking effort to "scan the environment" nationally for traffic signal potential best practices. A brief summary is provided below.

5.4.1. Improved Funding Strategies

Several studies exist on funding of signals at responsible agencies and several include some innovative strategies that were explored.

- One of the first steps to improving funding for traffic signals is to educate the public. When Georgia's Governor announced $116 million for traffic signals, he emphasized the importance of traffic signals in congestion reduction.[52] This funding seems to apply only to new traffic signal construction, not maintenance or operations. High profile announcements like Georgia's, however, can help bring attention to the benefits of traffic signals.
- There are various approaches to how funding is allocated as well. Examples found tend to relate to ITS structure or Transportation Management Centers, but the same funding allocation approach could be applied to signals system maintenance and operations. Denver Regional Council of Governments (DRCOG) has led the way in regional funding for traffic signals at the MPO/RPO level with their Regional Traffic Signal Improvement Program (RTSIP). RTSIP is fully funded by Congestion Mitigation Air Quality (CMAQ) funds with approximately 70% of funding allocated to field improvements and balance for administration and engineering.[53] In the Las Vegas Area Computer Traffic System (LVACTS), cost sharing is determined by formula. The basic rate structure is determined initially after a division of 50 percent for the City of Las Vegas and the remaining 50 percent proportionately for the other member agencies. [54] Agreement formulas include functions such as number of signals under LVACTS control. [55] Funding for LVACTS is proposed to the Board for annual approval[56] The partnership is managed under inter-local agreements designating the contractual terms of operation.[57] TranStar (Texas) Executive Committee is comprised of a representative from each of the agencies. [58] Each Agency contributes to the annual operating budget of the TranStar Traffic Control Center on a prorated basis relative to their occupancy and utilization of building components.[59]
- An example of a readily achievable public-private partnership is also outlined for a FHWA funded project in Minnesota (**see Exhibit 5.4**). Public partners contributed existing roadways, traffic control equipment, installation, ongoing maintenance and operation of the system, and staff, while private partners contributed technical expertise, training, equipment, and advanced technologies. [60] Partners combined financial and staff resources, expertise, technology, management strategies, and infrastructure.[61]

Exhibit 5.4: Public and Private Partners in Minnesota (ICTM) Program

Affiliation	Partners
Public	Federal Highway Administration
	Minnesota Department of Transportation
	Hennepin County Public
	City of Bloomington
	City of Richfield
	City of Edina
Private	Skyline Products, Inc.
	AWA Traffic System
	Rennix Corporation
	Traffic Control Corporation

Source: Minnesota Department of Transportation. Integrated Corridor Traffic Management. 2000.

5.4.2. Holistic Approach

The need to think about traffic signals broader geographic scale, be it corridor, county, region, district, or statewide, is imperative maximizing signal systems benefits that cross municipal boundaries. Examples found in the research include the following:

- Minnesota Department of Transportation (MnDOT) described its effort to create corridor-wide cooperation without changing current funding structures in one countywide project called Integrated Corridor Traffic Management (ICTM). Their study highlighted the partnering infrastructure as the most significant deployment benefit.[62] Information on cooperative agreements is obtainable from several sources.
- Traffic Management Center programs are documented for several states, including Arizona, California, Colorado, Georgia, Nevada, and Texas. Many of the funding structures of these programs were highlighted in **Section 5.4.1**. These systems also demonstrate how interjurisdictional cooperation is promoted. The Houston TranStar and Las Vegas LVACTS systems are models in maintaining local autonomy. In TranStar, each agency presides over the responsibilities of their own signal system thereby retaining local autonomy. Decisions determining timing parameters affecting more than one jurisdiction are made following discussion, and then implemented by the jurisdiction owning the intersection.[63] This method allows each jurisdiction to retain its own liability without transferring responsibility to adjoining agencies.[64] LVACTS leaves even more local autonomy to jurisdictions, maintaining only data collection and adjustment of coordination parameters.[65] Los Angeles County coordinates multiple traffic control systems (TCSs) on its arterial streets using a new Information Exchange Network (IEN), a program aimed at providing individual resources to agencies without effecting jurisdictional responsibilities.[66]
- Interjurisdictional cooperation can also take a variety of forms with traffic signal systems. There are detailed examples of the variations of agreements possible for inter municipal coordination, including a suburban Philadelphia example. Occasionally, agreements are formalized as in the case of Monroe County, New York

where there is a memorandum of understanding to address maintenance.[67] Typically these agreements are brought together at planning organization level. Reaching agreement is often more challenging than the technological difficulties.[68]

5.4.3. Planning / Policy Driven

Traffic signal planning can often be overlooked in favor of construction projects while policy remains stagnant with regard to changing signal technologies. There are several innovative ways to overcome these problems discovered in the research.

- These include formal and informal agreements between municipalities for corridor and region wide signalization projects. Vastly more interjurisdictional cooperation agreements are informal in nature, as is the case with an agreement between Upper Darby and Springfield Townships in District 6-0. (Delaware County)[69]
- The workshop addressed private sector concerns in traffic signal system planning and improvements. Public-private partnerships were included in many of the innovative practices highlighted elsewhere in this document, particularly in the technology and operations sections. These partnerships generally include traffic signal vendors and maintenance contractors. Public-private partnerships can also be used with other types of institutions, such as Maine Department of Transportation which partners with a utility company to replace outdated signals statewide.[70]

5.4.4. Institutional Responsibilities / Accountability

Institutional structures can limit the ability of traffic signal systems to adapt to changing technologies and policies. Research provided some to the following examples.

- One example on how to overcome this obstacle is with an oversight committee, such as with an Arizona example, that defines and enforces oversight policies. The Task Force was responsible for identifying areas for improvement under a set of standards for interagency coordination.
- Technology can also be used as with the Maryland State Highway Authority's (MdSHA) communications link to continuously test loop for detector failures. Minnesota has a computerized maintenance management system to keep track of maintenance issues. None of these systems are especially technologically complicated, but require the initiative and resources to create these systems.

5.4.5. Efficient Operations

Efficient operations are essential to getting the most out of installed traffic signal technology. There are varied examples of daily oversight and fine tuning of traffic signals to ensure maximum performance.

- In North Carolina work is being conducted to improve internet capabilities for the public as well as administrative functions and traffic signal timing changes. The Houston TransStar system is managed by transportation and emergency management personnel, allowing for increased oversight of emergency response issues.[71]

- Tying in traffic signals with ITS can often lead to improved efficiencies during events, with examples in Maryland, Pennsylvania, and Texas. The Maryland CHART (Chesapeake Highway Advisories Routing Traffic) and Philadelphia Traffic and Incident Management System (TIMS) are nationwide models. There is surprisingly little information about operational protocols of State Departments of Transportation in relation to traffic signals. There are many technical manuals and handbooks relating to traffic signal technology and operations.

5.4.6. Effective Training / Education

Education and training for public sector officials and the awareness for public at large is a key to increasing support for traffic signal improvements and ensuring maximum efficiency of existing systems. Research provides many examples.

- When linked with ITS capabilities, there are many options to reach out to the public via websites and cable television, as in a Seattle example. Generally, the website was seen as the most helpful tool by the general public and encouraged more repeat visits than the cable channel.[72]
- Training for traffic engineers and public officials can also improve efficiency whether it is an extensive course over several days, as with University of Idaho's Traffic Signal Summer Camp, or a more localized course covering a broader range of issues, as with the Consortium for ITS Training and Education (CITE)'s traffic signal timing courses.

5.4.7. Effective Use of Technology

Innovations in traffic signal technology are happening rapidly. It can be hard to keep current with the state of the practice. This accelerated change makes traffic signal pilot programs particularly important. There are several examples of innovative Advance Traffic Signal (ATS) technology rollouts from Minnesota, Michigan, and Georgia. Each system is tailored to the needs of its region, which is an inherent necessity of new technology.

- Cobbs County, Georgia uses an Advanced Traffic Management System (ATMS) controlled through a traffic control system to respond to congestion and incidents. The Minnesota example centers on the Minneapolis central business district's use of the Split Cycle Offset Optimization Technique (SCOOT) system.
- Oakland County, Michigan was one of the first areas of the country to test an adaptive traffic system in the form of their Sydney Coordinated Adaptive Traffic System (SCATS).
- A Minnesota Case study in Hennepin County highlights the use of SCATS across jurisdictional boundaries in conjunction with a freeway.
- The Metropolitan Model Deployment Initiative (MMDI) program initiated by the FHWA is a wealth of technological resources for several case study areas including Seattle, Phoenix, and San Antonio. All models show how technology must be tailored to unique corridor needs in order to be successful.

PHASE II – ISSUES EVALUATION

6. SOLUTION IDENTIFICATION AND PRIORITIZATION

Phase I “Issues Identification” and “Research and Benchmarking” along with stakeholder input formed the basis for the identification of potential solutions. The Study Team used these resources at a brainstorming session which yielded approximately 50 potential solutions.

Other potential solutions were identified and an initial and informal prioritization was developed through the feedback of stakeholders at a meeting held on September 22, 2004. Prioritized solutions represented an initial list for further research and analysis. Solutions were added, deleted or reprioritized based on the findings of the additional research and findings.

7. TIER I POTENTIAL SOLUTIONS

Twelve potential solutions were identified as a Tier I in priority. For purposes of this TAC study, Tiered 1 Potential Solutions denotes those areas or potential recommendations with the greatest anticipated impact. In order to further expand and assess these potential solutions, refined research and analysis was performed and a feasibility assessment was conducted. The refined research focused on the source issues, compared them to best practices, and documented benefits. The feasibility assessment considered barriers and risks as well as resource considerations.

REFINED RESEARCH AND ANALYSIS

- Source Issues
- Comparable Best Practices/ Lessons Learned
- Criteria/Benefits
- Other Benefits

FEASIBILITY ASSESSMENT

- Barriers to Implementation
- Risk Considerations
- Strategic Implementation Considerations
- Resource Considerations

The twelve potential Tier 1 solutions include:

- Develop an Asset Management System
- Pursue Tiered Operations and Maintenance on Critical Corridors
- Pursue Tiered Operations and Maintenance for most Signals

- Promote a "Holistic" Approach to Signal Management
- Expand Traffic Signal Enhancement Initiative (TSEI) and Congested Corridor Improvement Program (CCIP)
- Review and Update the Traffic Signal Permit Process
- Establish Operational Audits Program
- Complete Updates and Revisions to PennDOT Traffic Signal Publications
- Allocate a Portion of Any New Funding Increase to Signals
- Provide Incentives for Operational Enhancements
- Encourage Regional Maintenance Contracts with Operational Incentives
- Provide Incentives for Interjurisdictional Coordination

It should be noted that items 1 through 8 are not directly dependent on any new funding stream, but could be implemented more quickly and to a far greater level with the support of additional funding. Item 9 is a dedicated funding source that would allow for implementation of items 1 through 8 at a far greater level as well as support the funding needed for items 10 through 12.

Most of the recommendations are interrelated (**see Exhibit 7.1**) and need to be considered in relation to each other.

Recommendations are detailed on the subsequent pages after **Exhibit 7.1**. The format for each recommendation includes:

- A description of the recommendation and stakeholder considerations
- Comparable best practices
- Criteria evaluation and benefits
- Feasibility including barriers and risks
- Implementation considerations

Exhibit 7.1: Solution Relationships

	1. Develop of an Asset Management System	2. Pursue Tiered Operations and Maintenance on Critical Corridors	3. Pursue Tiered Operations and Maintenance for most Signals	4. Promote a "Holistic" Approach to Signal Management	5. Expand TSEI and CCIP	6. Review and Update the Traffic Signal Permit Process	7. Establish Operational Audits Program	8. Complete Updates and Revisions to PennDOT Traffic Signal Publications	9. Allocate a Portion of Any New Funding Increase to Signals	10. Provide Incentives for Operational Enhancements	11. Encourage Regional Maintenance Contracts with Operational Incentives	12. Provide Incentives for Interjurisdictional Coordination
1. Develop of an Asset Management System		X	X	X	X	X	X		X		X	X
2. Pursue Tiered Operations and Maintenance on Critical Corridors	X		X	X	X		X		X	X	X	X
3. Pursue Tiered Operations and Maintenance for most Signals	X	X		X	X		X		X	X	X	X
4. Promote a "Holistic" Approach to Signal Management	X	X	X		X		X		X	X	X	X
5. Expand TSEI and CCIP	X	X	X	X			X		X	X	X	X
6. Review and Update the Traffic Signal Permit Process	X						X	X		X	X	
7. Establish Operational Audits Program					X	X		X	X	X	X	X
8. Complete Updates and Revisions to PennDOT Traffic Signal Publications	X	X	X	X	X	X	X				X	
9. Allocate a Portion of Any New Funding Increase to Signals	X	X	X	X	X		X			X	X	X
10. Provide Incentives for Operational Enhancements		X	X	X	X	X	X		X		X	X
11. Encourage Regional Maintenance Contracts with Operational Incentives	X	X	X	X	X	X	X	X	X	X		X
12. Provide Incentives for Interjurisdictional Coordination	X	X	X	X	X		X		X	X	X	

7.1. Develop an Asset Management System

Before traffic signal systems can be enhanced, there must be a better understanding of existing assets—especially current operating performance. Pennsylvania's locally owned 13,600 signals are estimated to be valued at more than $1 billion ($75,000 each).The development of an asset management system would provide a tool to systematically evaluate signal system conditions and needs and would be consistent with a **holistic** approach to signal systems. An asset management tool would allow better planning, deployment, operations and maintenance of signal systems.

Asset management is a strategic approach to managing transportation infrastructure. It includes a set of principles and practices for building, preserving, and operating facilities more cost-effectively and with improved performance, delivering the best value for public tax dollar spent, and enhancing the credibility and accountability of the transportation agency. Fundamental elements of asset management include:

- A reliable and data-useful inventory of the infrastructure.
- Ensuring that programs, projects and services are delivered in the most effective way available.
- Informed decision-making based on quality information and analytic tools.
- Monitoring of actual performance and costs, and use of this feedback to improve future decisions.
- Identification and evaluation of a wide variety of options for achieving performance goals.

The vision for the system would be a multi-agency database tool that could perform a variety of functions and querying capabilities. Key data contained in the system is detailed in **Exhibit 7.2.**

Exhibit 7.2: Asset Management Features

Data Area	Key Features
Signal Location	➢ GIS system with mapping to show physical locations of signalized intersections ➢ Intersecting roads
General	➢ Permit number ➢ Owner/municipality/county ➢ Electronic (CAD or PDF) permit ➢ Photographs
Date	➢ Final acceptance and issuance of permit ➢ Revisions and dates
Hardware	➢ Manufacturer, model, and year
Interconnect	➢ Type of interconnect ➢ System software
Timing and Operations	➢ Operations type (time-of-day or traffic responsive) ➢ Timing plans and special timing plans (incident, homeland security, event) ➢ Date of timing plan ➢ Timing plan review and acceptance tool ➢ Available traffic counts

Exhibit 7.2: Asset Management Features

Data Area	Key Features
Maintenance	➢ Preventative maintenance schedule and status ➢ Response maintenance performed
Other Planning Data	➢ Traffic volume data ➢ Crash data ➢ Importance to intermodal uses
Financial	➢ Maintenance costs ➢ Operation costs ➢ Other

The development of an asset management system could be the platform for a streamlined timing modification procedure, which was a concern of many stakeholders. Currently, timing modifications must be requested in writing by the municipality and reviewed/ approved by PennDOT. Any change requires a revision in the permit.

An asset management tool could be used by a variety of stakeholders (**see Exhibit 7.3**). These stakeholders would include PennDOT, local municipalities, and planning organizations.

Exhibit 7.3: Asset Management – Stakeholder Utilization

Stakeholder	System Utilization Examples
Planning Organization	➢ Better understand needs and be able to strategically allocate resources by querying critical data such as age and condition of equipment, traffic volume and crash data
PennDOT BHSTE	➢ Better understand needs and be able to strategically allocate resources by querying critical data such as age and condition of equipment, traffic volume and crash data ➢ Strategically plan programs and initiatives such as Congested Corridor Improvement Program and Traffic Signal Enhancement Initiative ➢ Assess equipment and procurement needs at a statewide level ➢ More efficient response to complaints
PennDOT Districts	➢ Better understand needs and be able to strategically allocate resources by querying critical data such as age and condition of equipment, traffic volume and crash data ➢ Oversee signal system operations and maintenance ➢ Utilize as an information resource in District initiatives ➢ Assess equipment and procurements needs at a District level ➢ More efficient response to complaints
Local Municipalities	➢ Better understand needs and be able to strategically allocate resources by querying critical data such as age and condition of equipment, traffic volume and crash data ➢ Efficiently manage operations and maintenance ➢ Assess equipment and procurements needs at the local level ➢ Track and review financial data for signal systems ➢ More efficient response to complaints

7.1.1. Comparable Best Practices and Lessons Learned

Chicago's Regional Transportation Authority (RTA) developed a Regional Signal Integration Plan. One of the first tasks was to develop an asset management tool. The RTA decided upon a GIS-based signal inventory system, surveying each municipality in the region about location, manufacturer, age and other relevant information to ensure accurate and updated information[73]. GIS was also used in Operation Green Light, Kansas City's Regional Signal System program, and is a common management tool.

The FHWA recently published a state-of-the-practice review on signal system asset management by surveying existing practices throughout the country. The report uncovered several interesting trends. Foremost among the trends was the general reliance on signal optimization/simulation software as a main component of asset management, as well as inventory and maintenance management. Additionally, many groups reported keeping information on signal system components. A wide variety of software was used for asset management, which suggests that there is no industry leader in asset management software.

7.1.2. Criteria Evaluation and Benefits

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	If signal components are logged, preventative repair and maintenance could be programmed/scheduled/completed on a regular basis, thus reducing operational interruptions
Intersection Operations	Positive	If signal components are logged, preventative repair and maintenance could be completed on a regular basis, thus reducing operational interruptions
Crash Reduction	Positive	Safety can be better considered in the planning signal enhancement projects
Financial Savings	Positive	Provides a means to better manage resources
Intermodalism	Limited	Transit Signal Priority could be indirectly assisted. Signals in high freight concentration areas such as ports and rail yards could be better planned for/addressed
Public Perception	Positive	Quicker response to issues and complaints
Practical Feasibility	Positive	Low cost database technology makes this a modest and manageable initiative. Allows for ease of updating

7.1.3. Feasibility Assessment

Several PennDOT District Traffic Engineers mentioned utilizing asset management tools in varying forms. The fact that each District has its own unique methodology or set of collected data suggests that a statewide method may make asset management more feasible and beneficial.

BARRIERS TO IMPLEMENTATION

Potential barriers to implementation include:

- Agreement by stakeholders on the related concept of operations
- Lack of support and buy-in from other work groups(such as IT) that may be needed to maintain and operate such a system
- Initial need to input and verify a massive amount of data.

RISK CONSIDERATIONS

Possible risk considerations include:

- Investing resources in an asset management system without full and widespread deployment
- Ability to accurately develop the baseline database
- Ability to maintain support from upper management.

7.1.4. Implementation Considerations

An asset management tool is vital for efficient planning of other signal system programs and initiatives. For that reason, the TAC considers this solution as a foundation for all other recommendations in this report.

FHWA INVESTIGATION OF SIGNAL SYSTEM ASSETS MANAGEMENT

As stated previously, the FHWA Office of Transportation Management is conducting an Investigation of Signal System Assets Management Methodology and Process Elements project (Task Order Number CA81F042). The purpose of the project is to obtain a better understanding of operations-level asset management by examining the specific case of signal systems. Key products will include:

- A synthesis of existing signal systems asset management practices.
- A generic model of a signal system asset management system.
- A description of the elements of a signal system management system.
- Demonstration of how a signals asset management system could be used to support signal system management, operation and improvement decisions.
- Comparison of the signals asset management system concept to infrastructure-based and IT-based asset management systems.
- The model signal systems asset management system will include the following three key aspects of signal system operations and management:

  Physical - The specific physical components that make up signal systems (e.g., signal heads, loop detectors, video cameras, and controller boxes).

  System - The design features and operational characteristics of the traffic management function provided by the integrated set of components that make up the signal system.

  Personnel - The staff resources available for operating and maintaining the signals and the institutional and management approaches used to provide these staff resources.

This initiative is a valuable resource in the development of an asset management system.

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

Currently, two Districts (5 and 6) utilize a traffic signal asset management system. Several other districts have limited databases. A pilot or early action item could be to develop formal functional requirements for an asset management system, to review those requirements in comparison to existing systems, and to develop and deploy a system for testing and phased development.

7.2. PURSUE TIERED OPERATIONS AND MAINTENANCE ON CRITICAL CORRIDORS

Operations on critical corridors are a primary concern. Many of the signal systems along a specific corridor are operated individually by a local authority without the broader consideration of the entire corridor. A **holistic** approach would pursue tiered operations and maintenance along critical corridors across jurisdictional boundaries. Tiered operations and maintenance may include municipal maintenance and PennDOT and/or municipal operational responsibility.

This is consistent with the Department's Mobility Strategic Focus Area Executive Goal to "effectively and efficiently operate the transportation system." It is also consistent with the TEA-21 mandated ITS Regional Architectures which have been or are under development with in Pennsylvania. The Regional ITS Architecture is a framework for ensuring institutional knowledge, participation and coordination in planning for the implementation of ITS projects. It provides an organized framework for planning ITS integration through transportation planning and planning organizations business processes. Signal systems are a fundamental element in that framework.

The criteria for which corridors should be considered for tiered, interjurisdictional operations and maintenance include several considerations (**see Exhibit 7.4**). An asset management system would be a helpful in identifying critical corridors and systems. Ultimately, stakeholders must collectively agree that a regional and tiered approach is the best strategy for each specific corridor.

Exhibit 7.4: Critical Corridor Considerations

Criteria Area	Considerations
Functional Classification and Traffic Volumes	➢ Corridors that function as major arterials ➢ Corridors with average daily volumes exceeding a calculated threshold ➢ Corridors with peak hour volumes exceeding a calculated threshold
Existing Signal Systems	➢ Corridors with multiple complex jurisdictional signal systems ➢ Corridors with closely spaced signal systems with no apparent break between systems ➢ Corridors with an average signal density exceeding a calculated threshold
Special Needs	➢ Corridors vital to homeland security needs ➢ Corridors on designated evacuation routes ➢ Corridors that are utilized for incident detour routes from Interstate roadways ➢ Corridors that have recurring special event demands ➢ Corridor near ITS assets

Ensuring the performance of critical transportation corridors should be a concern of all stakeholders. As such, stakeholders need to facilitate better communication among the respective organizations and advance cooperative solutions that promote traffic signal coordination along critical corridors. Critical corridors may include the development of a Corridor Consortium (**see Exhibit 7.5**) that meets on a regular basis to discuss issues that relate to efficient transportation along each corridor.

An interjurisdictional and tiered approach to traffic signals along critical corridors will provide an opportunity for developing timing plans for incident/event management coordination. With systems properly operating, timings can be added to controllers for situations involving heavy traffic or detours for incidents occurring on adjacent routes. This type of coordination is currently lacking throughout the state and could greatly improve traffic flow during critical times.

Where appropriate, if there are operational facilities to support them, innovative systems such as adaptive control strategies **(see Section 7.8)** should be considered along critical corridors.

Exhibit 7.5: Critical Corridor – Stakeholder's Role

	Stakeholder	Role in Critical Corridor Programs
Critical Corridor Consortium	**Planning Organization**	➢ Regional oversight ➢ Identification of funding opportunities for corridor enhancement ➢ Identify other related planning issues or needs such as goods movement.
	PennDOT BHSTE	➢ Development of criteria and guidance for selection ➢ Oversee District implementation
	PennDOT Districts	➢ Corridor-wide operations
	Local Municipalities	➢ Local operations in coordination with District ➢ Maintenance activities ➢ Identify community concerns and issues
	Emergency Services	➢ Identify safety, response and enforcement concerns
	Transit Agency	➢ Identify transit related issues and concerns
	Business Representative	➢ Identify issues related to economic development

7.2.1. Comparable Best Practices and Lessons Learned

There are several good examples of tiered operations on a corridor-wide basis.

❑ In 2002, Los Angeles County began a program to coordinate signals across jurisdictions' traffic control systems on its arterial streets using an Information Exchange Network (IEN) that allows all control systems to be monitored and updated from one site[74]. The network was estimated to be able to provide coordination for 5,300 intersections by 2004.

❑ In Orange County, Florida, the Traffic Management Center (TMC) headquartered in Orlando provides coordination for 384 signals[75]. The City of Orlando staffs the TMC, thus providing a strong lead agency to the project.

❑ In the Delaware Valley, Upper Darby, Springfield, and Philadelphia have an informal agreement to provide signal coordination. This agreement has been in place for over 20 years with much success.

Where disputes over signal control does not allow for a lead agency, communities can look to Montgomery County, Maryland where three agencies coordinate signals without ceding control of signals within their jurisdiction. The key is an agreement between the jurisdictions to have similar cycle lengths along overlapping corridors and ensuring that cycle changes in each jurisdiction are set for the same time of day[76].

Part of successful coordination is municipal buy-in. In Arizona, a program called AZTech was established to coordinate signals between Phoenix and several of its surrounding communities along Route 202. A communications infrastructure was created so all municipalities could work together via AZTech servers. Workstations were installed in each jurisdiction. A regional traffic control and management plan was created with input from all relevant agencies. The result of this effort was full buy-in from the communities[77].

Such coordination may not require additional funding sources. If a lead agency is appointed for coordination, much of the operating budget can be paid from one jurisdiction to the other without increasing costs. This may be particularly effective if the lead agency is significantly larger than the other participating jurisdictions, as in the case of Philadelphia's agreement with Upper Darby and Springfield. In cases where no lead agency is identified, or all agencies are relatively equal in size, new funding may be required for an oversight committee or organization. While Montgomery County exemplifies coordination without a lead agency, PennDOT can also look to the Los Angeles County model. The LA project is funded by transportation-dedicated revenue from sales tax, allowing for the creation of new positions dedicated to signal system operation and management. Costs can be kept at a minimum by timing installation of necessary equipment in concert with other corridor construction and reconstruction projects, which happened successfully in San Antonio[78].

7.2.2. Criteria Evaluation and Benefits

This solution is projected to have significant positive impact on the evaluation criteria. Previous efforts of interjurisdictional coordination have yielded considerable decreases in network delay and travel time. Coordination can improve intersection operations dramatically by providing a central operating system that better responds to changes in travel demand. Public perception of such an effort is certain to be viewed positively given its reduction in travel time. With traffic routinely listed as a major concern in communities, particularly larger communities, any system that improves travel time will be viewed as beneficial. Finally, the feasibility of such an effort is high, making this solution a highly recommended one.

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	On any interjurisdictional corridor, there are potential reductions in delay
Intersection Operations	Positive	Coordination requiring central monitoring should reduce delay from signal interruptions or poor signal timing
Crash Reduction	Unknown	--
Financial Savings	Variable	Adding a new agency to manage operations will increase costs, but that should be offset by travel savings
Intermodalism	Positive	Transit will benefit from improved operations. Potential benefit to freight corridors.
Public Perception	Positive	Delay reductions are certain to be viewed positively, particularly if costs are low
Practical Feasibility	Positive	Many examples of demonstrable success

7.2.3. *Feasibility Assessment*

This solution has a high likelihood of implementation success given the past success both outside of the state and within it. Interagency coordination can often be conducted without incurring any new costs. In the best practice examples where additional funding is necessary, there are several examples of techniques that can minimize expenditures.

BARRIERS TO IMPLEMENTATION

Potential barriers to implementation include:

- ❑ Lack of buy-in by all necessary stakeholders/ municipalities within a critical corridor
- ❑ Lack of concurrence by involved parties for shared responsibilities and resources
- ❑ Human resource needs for operating agency
- ❑ May require 24/7 commitment.

RISK CONSIDERATIONS

Possible risk considerations for this recommendation include:

- ❑ Poor upfront communication and coordination could lead to future disagreements and failure of the consortium.

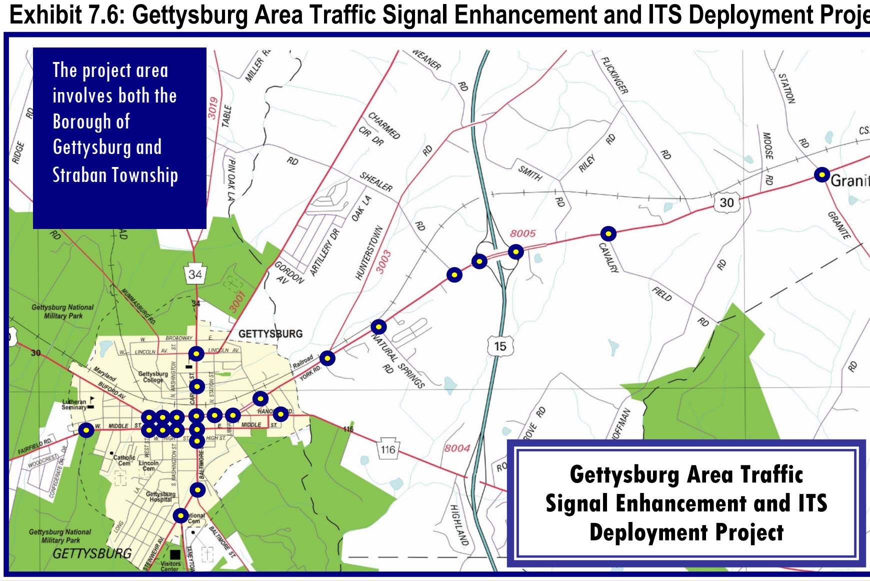
7.2.4. *Implementation Considerations*

Due to the limited amount of resources and infrastructure needed, tiered operations on critical corridors could be implemented in the short-term.

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

There are several corridors that are viable candidates for pilot programs. Gettysburg Area Traffic Signal Enhancement and ITS Deployment Project (**see Exhibit 7.6**), which is under design, would provide a good opportunity to pilot this solution.

Exhibit 7.6: Gettysburg Area Traffic Signal Enhancement and ITS Deployment Project



The Congestion Corridor Improvement Program (CCIP) discussed in more detail in **Section 7.5** may be another mechanism for piloting such an initiative. Since the CCIP requires that funds be set aside in the TIP for implementation of improvements. These funds could be used to implement an interjurisdictional corridor with a pilot for PennDOT to assume operational oversight.

Key next steps include:

- ❑ Develop detailed criteria
- ❑ Develop memorandums of understanding
- ❑ Pilot several subject corridors.

7.3. PURSUE TIERED OPERATIONS AND MAINTENANCE FOR MOST SIGNALS

Although a tiered, interjurisdictional effort along critical corridors may be the best approach in the short-term, a long-term solution may include a tiered operations and maintenance for all signal systems throughout Pennsylvania. This **holistic** approach to signal systems would improve interjurisdictional coordination through regional and statewide signal committees (**see Exhibit 7.7**). A regional approach would promote more effective management practices for even isolated traffic signals.

Exhibit 7.7: Statewide Tiered Operations – Stakeholder's Role

	Level	Responsibility
Tiered Operations and Maintenance	**State Signal Committee**	➢ Statewide oversight and priority setting
	Regional Signal Committee	➢ Regional oversight and prioritization ➢ Identification of funding opportunities for signal enhancements
	District	➢ Oversee signal system operations ➢ Implement operational revisions
	Critical Corridors Consortium	SEE ALSO SECTION 7.2 ➢ Coordinate operations and maintenance along critical corridors
	Local Municipalities	➢ Perform basic signal modifications ➢ Perform/ coordinate basic maintenance activities ➢ Jointly oversee signal system operations and maintenance in some cases (larger municipalities with the majority of a regions traffic signals)

Delaware Valley Regional Planning Commission

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The ITS Coordinating Council (ICC)

Chair: John Coscia, DVRPC/NJ DOT/PennDOT
Staff Coordinators: Stan Platt/John Ward
Meeting Frequency: as needed
The Delaware Valley ITS Coordinating Council consists of policy-level representatives from approximately 30 regional stakeholders and is currently chaired by DVRPC. The Council meets on an as-needed basis to establish policy and direction for the ITS Technical Task Force.

The ITS Technical Task Force (TTF)

Chair: Rich Montanez, City of Philadelphia
Staff Coordinators: Stan Platt/John Ward
Meeting Frequency: Bi-monthly Composed of technical staff representatives from over 35 regional stakeholders, the Delaware Valley ITS Technical Task Force is the focal point of regional ITS coordination. Chaired by an elected member of the committee, and meeting approximately bi-monthly, the Task Force is a forum for agencies to share information on ITS deployments, develop a consensus on regional ITS issues, respond to federal and initiatives, and develop an annual action plan. It has the ability to establish subcommittees to tackle specific issues as they arise. As a technical-level group, it directs DVRPC's ITS planning activities that in turn support the Task Force.

Regional Signal Committees would work with planning organizations as well as PennDOT and other transportation partners in the regional oversight and prioritization of signal system enhancements, as well as promote the importance of addressing signal systems. Regional Signal Committees may be led by planning organizations and may be similar to ITS subcommittees that exist within many planning organizations today.

Participation in Regional Signal Committees should not be time-intensive and should include representation from Critical Corridor Consortiums including special representation from:

- ❑ Planning Organizations
- ❑ PennDOT BHSTE

- PennDOT Districts
- Local Municipalities
- Emergency Services
- Transit Providers
- Business Representatives.

The State Signal Committee is similar to the establishment of a Signal System Leadership Forum, which is identified as a "Medium" level priority in **Section 8.2**. The State Signal Committee should include representation from regional committees and should also include representation from private entities and research groups such as:

- Vendors and Suppliers – provide insight into new technology and products
- Maintenance and Construction Contractors – provide insight into maintenance activities as well as construction methods and practices
- Consultants – provide collaborative insights from various clients
- Research Institutions – provide insight on ongoing research activities
- Professional Organizations – organizations such as Institute of Transportation Engineers (ITE), Intelligent Transportation Society of America (ITSA), International Municipal Signal Associations (IMSA) and American Association of State Highway and Transportation Officials (AASHTO) provide insight on sponsored research and activities such as national meetings and training opportunities
- National Organizations – organizations such as FHWA provide guidance and insight of the state-of-the-practice at a national level.

This committee should meet bi-annually to review the state-of-the-practice of traffic signals, discuss issues and concerns, and identify training opportunities. It should be the forum for ongoing state-wide strategy development and innovation.

7.3.1. Comparable Best Practices and Lessons Learned

State surveys conducted by the consulting team found that the vast majority of state departments of transportation have a greaterdegree of control over signals and signal systems than does PennDOT. Of the 13 states surveyed, only Tennessee's DOT had no stake in signal ownership, operation or maintenance. In general, state agencies own signals on state roads, counties own signals on county roads, and municipalities own signals on municipal roads.

Operation and maintenance is not as uniform from state to state.. Several states have particularly innovative approaches. The Missouri DOT maintains signals on state roads, with other jurisdictions maintaining signals on their respective roads. However, a large number of cross-jurisdictional roads has required the DOT to allow municipalities to handle signal timing on state roads that traverse cities. This system encourages the state DOT to help jurisdictions coordinate timing plans.

In New Jersey, the system is slightly different. While the state owns signals on state roads, counties own signals on county roads, etc, the state takes a hierarchical approach to determining who controls intersections that cross ownership. When two roads intersect, the higher authority has absolute control over the intersection. For example, when a city road and a county road intersect, the county has control over all the signals at that intersection, including signalization, timing, and upgrading. Construction costs at these intersections are split 50/50, but the higher authority acts as the contractor. This system ensures a consistent hierarchy of decision-making, eliminating potentially difficult interjurisdictional coordination efforts. However, the down side is that there are grumblings among smaller jurisdictions over having so little control over signal decisions, particularly since they foot half of the construction bill.

Kansas City Operation Green Light

Operation Green Light is a joint effort between state and local governments to synchronize traffic signals on 1500 intersections throughout the Kansas City area in order to improve traffic flow and air quality. The Mid-America Regional Council (MARC), the area's MPO, is the umbrella under which the Missouri and Kansas Departments of Transportation and 17 area cities work together to develop coordinated timing plans and signal communication systems. The coincidence of several key events helped bring Operation Green Light into existence. In 1998, MARC allocated funds to study the impact of traffic signal coordination on emissions reduction. That same year the Missouri DOT and the Public Works Department of Kansas City conducted a study addressing common hardware standards for traffic signal equipment. In the summer of 1998, the two studies were combined and resulted in a recommendation for regional signal timing coordination. With its recent eligibility for CMAQ funds, the Kansas City region was able to initiate Operation Green Light. At the present time, the region is assembling resources and working with local agencies to deploy signal-timing plans. Operation Green Light is expected to reduce traffic delays, improve traffic flow, reduce emissions, and assist in managing changes in traffic patterns resulting from a new freeway management system.

Information Available at www.marc.org/transportation/ogl/

In South Dakota, state roads running through other jurisdictions are owned by the state but operated and maintained by the jurisdictions without any compensation by the state. To compound this problem, the state has veto power over all timing and upgrading changes to their signals. One surveyed community in South Dakota reported that the state DOT is rarely amenable to local changes, making coordinated signalization difficult if not impossible. Besides being a challenge for communities, this system can be a dangerous proposition. For smaller communities, they often lack the funds to properly maintain the state-owned signals in their towns, thus leaving them unattended. This could pose liability concerns for the DOT.

These concerns can be reduced by involving regional organizations that are better able to stay attuned to local needs and abilities. In Colorado, the Denver Regional Council of Governments (DRCOG) runs the Regional Traffic Signal Improvement Program (RTSIP), a program that allows DRCOG municipalities to maintain ownership of signals but sets timing plans to reduce interjurisdictional delay and travel time.[79] In Tucson, Arizona seven agencies coordinate signal systems through the Pima Association of Governments Transportation Planning Division (PAGTPD). A shared traffic management system operates 400 signals throughout Pima County, while still allowing each jurisdiction to own and set timing plans for its signals. The shared traffic management system makes interagency coordination easy without forcing any agency's hand in signal timing issues.[80]

7.3.2. Criteria Evaluation and Benefits

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	A tiered approach to signal systems will likely make interjurisdictional coordination easier, thus reducing delay and travel time
Intersection Operations	Positive	Operations will likely improve the most in the smaller communities whose signal resources are severely limited
Crash Reduction	None	---
Financial Savings	Negative	In the short-term, any change in ownership, operation or maintenance of signals will be costly
Intermodalism	Positive	Improved transit operations could be a benefit
Public Perception	Unknown	If interjurisdictional coordination is made easier, public perception should be favorable. However, this is as yet unknown.
Practical Feasibility	Low	No findings on the practical considerations of changing a statewide signal policy make the feasibility low.

This solution has benefits in delay and travel time, and in intersection operations. Those who benefit include the smaller jurisdictions currently struggling to maintain and operate their signals. There are concerns that there will be significant financial costs in the short run, and therefore will inhibit the feasibility of this solution. While this solution seems to be a sweeping change, one must consider how advances in technology might make this far more feasible and beneficial.

7.3.3. Feasibility Assessment

This solution will be difficult to implement. Despite nationwide success with the tiered approach, convincing municipalities to cede control of signals may be a difficult proposition. Research failed to locate any examples of states that switched to a new signal hierarchy, which could have been used as a case study for such a transition.

BARRIERS TO IMPLEMENTATION

Potential barriers to implementation include:

- Lack of long-term buy-in from local, state, and regional planning organizations
- Lack of an overall strategic plan to guide implementation
- If there is a lack of success with regard to tiered operations and maintenance along critical corridors, support for this broader solution way erode.
- Lack of funding to support initiative
- Human resource needs
- May require 24/7 commitment.

RISK CONSIDERATIONS

Possible risk considerations include:

- Poor planning and coordination upfront could lead to the solution's failure.

7.3.4. Implementation Considerations

As was discussed in **Section 7.2**, tiered operations and maintenance on critical corridors can be more easily piloted and tested than a statewide approach. The success of the corridor approach should be used as a barometer to determine if the broader approach should be attempted on a statewide level.

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

Key next steps include:

- Monitor tiered operations and maintenance on critical corridors
- Begin development of a strategic implementation plan.

7.4. PROMOTE A "HOLISTIC" APPROACH TO SIGNAL SYSTEMS MANAGEMENT

The solutions discussed in sections 7.1 through 7.3 lay the foundation for a **holistic** approach to signal systems management (**see Exhibit 7.8**). The development of an asset management system and a tiered approach to operations and maintenance establishes the framework for PennDOT and planning organizations to develop a Regional Traffic Signal Improvement Program (RTSIP).

Furthermore, this solution is consistent with PennDOT's emerging Mobility Plan and Transportation Systems Operations Plan (TSOP). The TSOP defines: Why, What, and How with regard to managing capacity. "Traffic Signal Operations" is one of four critical elements of the TSOP. As the TSOP continues to be developed, it will be presented to District personnel and to planning partners. This will be a significant opportunity to promote signal systems management at a holistic level.

Exhibit 7.8: Elements of a Holistic Approach

Recommendation	Role in Holistic Management Approach
1. Develop of an Asset Management System	➢ An asset management tool would allow better planning, deployment, and operations and maintenance of signal systems by all stakeholders including PennDOT, planning organizations, and municipalities.
2. Pursue Tiered Operations and Maintenance on Critical Corridors	➢ A holistic approach would pursue tiered operations and maintenance along critical corridors across jurisdictional boundaries. ➢ Tiered operations and maintenance may include municipal maintenance and PennDOT and/or municipal operational responsibility. ➢ Stakeholders need to facilitate better communications between the respective organizations and collaborate for traffic signal coordination along critical corridors
3. Pursue Tiered Operations and Maintenance for most Signals	➢ Long-term solutions should include tiered operations and maintenance of most signal systems throughout Pennsylvania. ➢ This holistic approach to signal systems would improve interjurisdictional coordination through regional and statewide signal committees. ➢ A regional approach would promote more effectively management practices for even isolated traffic signals. ➢ Regional Signal Committees would work with planning organizations as well as PennDOT and other transportation partners in the regional oversight and prioritization of signal system enhancements.
4. Promote a "Holistic" Approach to Signal Systems Management	➢ Develop a formal Regional Traffic Signal Improvement Program (RTSIP). ➢ Projects/ investments need to demonstrate quantifiable benefits.

To establish a holistic approach to signal system management, several elements need to occur:

- ❑ Stakeholders need a tool to assess regional traffic signal needs (asset management tool) and need to prioritize signal enhancement projects (RTSIP)
- ❑ Improvements for operations should be routinely considered in the funding process through the involvement of ITS Coordinating Councils and Regional Signal Committees

- ❑ Traffic signal enhancements and operation need to be consistent with and supported by the District's TSOP.
- ❑ Projects/investments must demonstrate quantifiable benefits.

This is approach is consistent with the mandated ITS Regional Architectures. The Regional ITS Architecture is a framework for ensuring institutional knowledge, participation and coordination in planning for the implementation of ITS projects including signal systems. It provides an organized framework for planning ITS integration through transportation planning and planning organizations' business processes.

7.4.1. Comparable Best Practices and Lessons Learned

The State of Minnesota instituted Guidestar, a statewide integrated ITS. Guidestar is a multiyear activity that provides strategic direction and oversight for ITS research, field operational tests, deployment support, and integration projects throughout the state. One aspect of Guidestar focuses upon interregional corridors that are important to the regional economy. Within these corridors, Guidestar established a project that focuses on an arterial in the Twin Cities metropolitan region which supports thousands of trips per day and traverses three jurisdictions. In this corridor, the Minnesota Department of Transportation (MNDOT) operates nine traffic signals along this highway while local agencies operate over twenty signals in close proximity. This project will deploy twisted pair technology throughout the corridor, a control system for traffic signals, CCTV cameras, and dynamic message signs.[81]

In the Phoenix, Arizona metropolitan area, transportation systems, operational procedures, and priorities are all under the jurisdiction of each individual city. Many major arterial corridors cross several jurisdictions that often include multiple traffic signal systems. However, a few organizations provide a foundation for regional transportation operations coordination and management including the Maricopa County Association of Governments ITS Committee and the East and West Valley Traffic Signal Timing Groups. The ITS Committee developed a common vision and short-term operational goals. To address these goals, a series of initiatives and associated action steps were created such as the initiative of coordination of traffic signal timing along key corridors.[82]

7.4.2. Criteria Evaluation and Benefits

Treating traffic signal system management in a holistic fashion can serve three important purposes. First, it presents an operations vision and direction for the future of transportation system management and operations based on a holistic view of the corridor or region. Second, it can garner commitment from agencies and jurisdictions for a common regional approach to transportation management and operations. Third, it provides an opportunity to strengthen the linkage between regional planners and managers responsible for transportation operations by providing a coherent operations strategy for consideration in the long range planning process.

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	Decrease delays and travel time when operations along and in close proximity to significant corridors are conducted by one entity
Intersection Operations	Positive	Improves traffic flow when operations along and in close proximity to significant corridors are conducted by one entity
Crash Reduction	Limited	Better ability to manage traffic incidents as well as better consideration of safety related improvements to signals
Financial Savings	Positive	A framework is establish to address the most cost-effective signal improvements consistent with available funding
Intermodalism	Positive	Allows for ability to adjust hauling schedules
Public Perception	Positive	Positive public perception of municipalities and other governmental entities working together to address common issues
Practical Feasibility	Moderate	There are several potential barriers to implementation

7.4.3. *Feasibility Assessment*

There are a few potential barriers to implementing a holistic approach to traffic signal systems management. Traffic signals in Pennsylvania are owned, operated, and maintained by individual municipalities. Therefore, municipalities typically view their traffic signal responsibilities from the perspective of their individual jurisdiction. Moreover, municipalities are usually most concerned with delivering services that respond to immediate and near-term imperatives and are not expected to prepare long-term multi-jurisdictional plans. The greatest challenge may come in convincing individual municipalities to share resources and responsibilities to achieve significant improvements in a regional traffic signal management approach. Incentives may be necessary as a practical consideration.

BARRIERS TO IMPLEMENTATION

Potential barriers to implementation include:

- ❑ Inability to garner buy-in from local municipalities in addressing regional needs
- ❑ Inability to garner support from high-level decision makers that operations is a viable funding area.

RISK CONSIDERATIONS

None identified.

7.4.4. *Implementation Considerations*

Implementation schedules may vary by region. Regions with well-organized planning organizations, as well as those with ITS Councils may be more equipped to pilot and pursue such a solution.

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

Key next steps include:

- ❑ Develop Regional Signal Committees
- ❑ Pilot initiative in two regions
  - Urban – Philadelphia/ DVRPC
  - Rural – To Be Determined.

7.5. EXPAND TRAFFIC SIGNAL ENHANCEMENT INITIATIVE (TSEI) AND CONGESTED CORRIDOR IMPROVEMENT PROGRAM (CCIP)

Both the Traffic Signal Enhancement Initiative (**see Exhibit 7.9**) and the Congested Corridor Improvement Program (**see Exhibit 7.10**) are valuable tools in congestion reduction. These **holistic** approaches evaluate systems across jurisdictional boundaries and involve stakeholders at various levels.

Exhibit 7.9: Traffic Signal Enhancement Initiative

Traffic Signal Enhancement Initiative	
Background	➢ The Traffic Signal Enhancement (TSEI) Initiative called for PennDOT to "partner with municipalities to identify traffic signals that need to be retimed, upgraded, or better integrated into an overall congestion management strategy."
Goal/ Outcome	➢ The goal of the TSEI is to reduce travel times and delay on specified signalized corridors. The TSEI seeks to optimize traffic flow through signalized intersections. ➢ All projects under the TSEI must have traffic flow as their primary focus, but safety enhancements may be included as an additional benefit. Moreover, PennDOT focuses on corridor-based projects but will consider improvements to grid systems or isolated intersections if sufficiently justified.
Status	➢ Implementation of the TSEI began with a $1 million set aside in PennDOT's 2001-2002 and 2002-2003 Highway Administration Business Plans. ➢ For fiscal years 2003-2004 and 2004-2005, $1.2 million has been allocated to the TSEI. Projects for the TSEI are submitted by the Traffic Signal Section in each District Traffic Unit. Each District may submit a maximum of two municipally-supported projects for consideration each year.

Exhibit 7.10: Congested Corridor Improvement Program

Congested Corridor Improvement Programs	
Background	➢ PennDOT initiated the Congested Corridor Improvement Program (CCIP) to identify congested corridors in the Commonwealth and, in conjunction with its partners, define and implement needed improvements. ➢ Transportation corridors and associated improvements are identified in partnership with MPO's/RPO's including utilization of existing congestion management systems (plans).
Goal/ Outcome	➢ The proposed improvements are directed at activities such as roadway geometry, signal operations, access management, multimodal initiatives, intelligent transportation systems (ITS), traffic regulation techniques, transportation demand management (TDM) measures, and planning and zoning practices that are appropriate for a particular transportation corridor.
Status	➢ CCIP studies have been complied for 17 corridors and eight corridors are underway. ➢ For fiscal year 2003-2004 and for future years, $1.2 million was allocated.

The TSEI focuses primarily on signal enhancement issues and other operational improvements. Since the program is managed and funded by PennDOT, improvements are implemented in a timely manner provided other stakeholders concur with the improvements.

The CCIP study phase is managed by PennDOT, and the design and implementation of physical improvements are funded by planning organizations or the local authorities. Since the

CCIP focuses on a broader range of potential solutions, stakeholder "buy-in" is critical to the success of each corridor.

Program	TSEI	CCIP
Number of Corridors Studied	19	16
Average Delay Reduction	20.1%	15.4%
Average Benefit/ Cost Ratio	15.9	7.2

Both programs have been determined to reduce delay with a higher benefit than the costs for implementation. Corridors in both rural and urban areas have been studied and positive benefits have been identified.

Each program's impact should be extended by increasing funding at a minimum rate of ten percent per year; however, these programs will not address the issues of congestion and signal systems without the support of other recommendations contained in this study. However, a ten percent increase in TSEI and CCIP funding in no way satisfies the funding needs for signals within the Commonwealth. This modest increase in funding is recommended because these programs have generally resulted in improvements with good benefit to cost ratios.

Additionally, both processes should be refined, if needed, in order to make implementation of improvements as timely as possible. Program results should continue to focus on improvements such as timing plans that can be implemented without additional study.

7.5.1. Comparable Best Practices and Lessons Learned

The objective of the CCIP is to identify congested transportation corridors within the Commonwealth and to define and implement needed improvements that will reduce peak hour travel time and/or system delay on the transportation corridor by 20 percent.[83] Best practice research found only one other state with a similar program. Washington State has a congested corridor improvement program that was created in 2002. The program allocated $10,000,000 over a three year period for congestion improvement funding in metropolitan areas. The funding can be used for roadway widening, channelization, signalization, HOV lanes or ITS. Twenty percent matching funds from the metropolitan area is expected for all projects under the congestion program.

Oregon's Traffic Signal Operations Program has similar aims as PennDOT's TSEI - focusing on efficient traffic signal operation. Operational improvements such as retiming or upgrades are eligible for funding under this program[84]. In Washington State, $1 million has been provided by the state government for use on upgrading ITS, and in particular for improving traffic signals, throughout the state[85]. Austin, Texas began a major signal improvement project in 2000 that cost approximately $21 million. The enhancements were funded through a 1998 bond initiative, as well as through funding from the local MPO[86]. In Montgomery County, Maryland, part of their transportation funding is allocated towards a pilot traffic signal enhancement program that is aimed at improving intermodalism through pedestrian signals.

7.5.2. Criteria Evaluation and Benefits

Projected positive impacts include reductions in network delay and travel time, improvements to intersection operations and practical feasibility. However, financial savings and crash reduction are minimal, while public perception is unknown.

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	Like other solutions, network efficiency is this solution's overarching purpose
Intersection Operations	Positive	Washington's program explicitly lists signalization as an appropriate use of funds for their TSEI
Crash Reduction	Positive	Crash history is considered as part of study phase in order to identify improvements
Financial Savings	Minimal	Expansion of the programs in the short term may be offset by increased efficiency and lower capital cost in the long-term
Intermodalism	Positive	Pedestrian and transit is often considered as part of both programs
Public Perception	Unknown	No data found on public perception
Practical Feasibility	Positive	Several communities have shown different methods for making this solution work

7.5.3. Feasibility Assessment

Both initiatives are demonstrably feasible since they are ongoing. The most significant barriers are gaining cooperation and support of funding for both programs.

BARRIERS TO IMPLEMENTATION

Potential barriers to implementation include:

- Inability to achieve interjurisdictional cooperation
- Inability to garner support for increased funding.

RISK CONSIDERATIONS

None identified.

7.5.4. Implementation Considerations

Implementation has occurred since both programs are ongoing.

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

Key next steps include:

- Continue to document and promote program successes and benefits
- Continue to identify subject corridors
- Acquire additional funding for existing and expanded program, with the justification being the high benefit-cost.

7.6. REVIEW AND UPDATE THE TRAFFIC SIGNAL PERMIT PROCESS

The review and update of the existing traffic signal permit process falls under **institutional responsibility/ accountability**, but also offers opportunities to more efficiently operate and manage signal systems.

The review and update should be divided into two phases: **Technical and Legal**. By addressing each phase individually, there is a better likelihood that one phase will not adversely affect the progress of another phase.

Existing Traffic Signal Permit Language

In accordance with the Vehicle Code, the Secretary of Transportation hereby approves the installation and operation of a traffic signal at the intersection of INTERSECTION NAME.

This installation shall be in accordance with the Vehicle Code and the Regulations for traffic signs, signals, and markings of the Department of Transportation, and shall conform to the following requirements and those contained on the attached sheets.

All work performed by the Permittee in the erection of the traffic signal shall be under and subject to the direction of the Secretary of Transportation or his authorized representatives. The said Permittee shall use due diligence in the execution of the work authorized under this permit and shall not obstruct or endanger travel along the said road. All operations must be conducted so as to permit safe and reasonable free travel at all times over the road within the limits of the work herein permitted.

The Permittee covenants and agrees to fully indemnify and save harmless the Department of Transportation and assume all liability for damages or injury, occurring to any person, persons or property through or in consequence of any act or omission of anyone working on the construction, or from faulty maintenance or operation of such traffic signal.

The Secretary of Transportation, by law, reserves the right to revoke and annul this permit if the Permittee shall at any time willfully or negligently fail to comply with the conditions contained in this permit, or, upon changes in traffic conditions, fail to make any changes in the construction or operation of this signal, or to remove it, when so ordered by the Secretary of Transportation; or if this installation in not in operation within twenty-four (24) months of the receipt of this permit. The Permittee shall maintain the signal in a safe condition at all times. The Permittee shall not make any change in the construction or operation of this traffic signal without prior written approval of the Secretary of Transportation.

The existing signal permit process creates responsibility for the construction, operations and maintenance of traffic signals, but has been criticized for a variety of reasons by stakeholders. Some common criticisms have included the following:

- ❑ As it is currently worded, the permit does not provide a realistic mechanism for enforcement of the permit conditions.
- ❑ The current practices associated with the permit process do not provide the permittee with any operational flexibility.
- ❑ The current practices associated with the permit process create a timing modification process that can be inefficient due to needed reviews and approvals.

- The current practices associated with the permit process do not fully include the identification and tracking of specific technologies utilized.
- The application of traffic signal permits vary by PennDOT Engineering District.
- The traffic signal permit often represents "as-designed" conditions and does not necessarily represent "as-built" conditions.
- The language associated with maintenance and operations is vague and does not give specific guidance.
- The existing permit process does not adequately consider signal systems.

These criticisms may be subjective, but illustrate a theme that it may be an appropriate time to review and update the traffic signal permit process. Key considerations in the review and update should include:

- Review the legal aspects of the permit with regard to design and construction, as well as, maintenance and operations. Provide clear language regarding the responsibilities of all parties as well as clear guidance on oversight practices.
- Allow operational flexibility within certain parameters. Although clearance intervals and phasing may need rigid oversight before revisions are made, flexibility (within reason) should be permitted in cycle lengths and phase splits provided PennDOT is notified of changes. Consideration should be given to tracking timing and phasing parameters on a separate page so minor changes do not necessitate a change to the permit plan sheet.
- Better track key technologies deployed at each signal such as controller type and preemption so that improvement projects can be better planned. Also, communication and conduit should be tracked as well.
- Review District preferences and revise basic guidelines for traffic signal permits.
- Require that the party constructing the traffic signal prepare a post-construction traffic signal permit to reflect "as-built" conditions.
- Identify on the permit, if the signal is part of a system, what type and what other intersections are in the system.

The revision of the permit process provides an opportunity to address Highway Occupancy Permit (HOP) and developer funded signals, which is an area of stakeholder concern. These are discussed in **Section 8** under Tier II, but include:

- Revise HOP process to address corridors or signal systems and not specific signals only
    - Requires new signal installation projects to consider the entire traffic signal systems resulting in improvements across jurisdictional boundaries
    - Provides better timing of traffic signals

- Revise HOP process to require signal fine-tuning through road bonds and/or escrow
  - Delay and congestion will be reduced since timings will be adjusted to reflect field conditions
  - Some of the financial burden of the municipalities mat be offset by developers

Another potential solution, which is identified in detail in **Section 8**, is the development of a systems permit. Two districts currently utilize a systems permit in addition to individual intersection permits. The benefit of a systems permit is that consideration is given to an entire system when a change is made to any intersection within the system; therefore, system operations are considered along with individual intersection operations.

7.6.1. Comparable Best Practices and Lessons Learned

There are few comparable best practices documented with regard to traffic signal permitting. Most examples identified deal with the relationship and the responsibilities of varying stakeholders.

One relevant example is the Oregon Transportation Planning Rule (TPR) that calls for strategies that increase the efficiency, safety, capacity or level of service of a transportation facility without increasing its size. As such, the Oregon TPR requires local governments, whenever financially possible, to update existing traffic signal systems to improve traffic flow. The Oregon TPR encourages municipalities to give priority to improving existing traffic signal systems including reviewing traffic signal warrants. This will enable Oregon municipalities to update and maintain existing signal systems, interconnect and coordinate signals, and eliminate unnecessary signals.[87]

7.6.2. Criteria Evaluation and Benefits

The traffic signal permitting process promotes statewide consistency. The benefits of reviewing and updating the traffic signal permit process include a more effective operation of a signal or a signal system.

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	Updated permits will reflect current conditions and can accurately address changes since the original permit was issued
Intersection Operations	Positive	Facilitates intersection consistency along corridors even with changing traffic/land use patterns
Crash Reduction	Positive	Updated permits will reflect current conditions and may serve to reduce crashes through accurate incident management prevention systems
Financial Savings	Positive	Reviewing and updating signals and signal systems is a cost-effective solution to decreasing congestion, and is less costly or controversial than increasing capacity through lane widening
Intermodalism	Positive	Signal spacing and timing updates may lessen potential conflict points with trucks and tractor-trailers
Public Perception	None	
Practical Feasibility	Positive	

7.6.3. Feasibility Assessment

Updating the permit process requires support by PennDOT Districts, local municipalities, and legal counsel. Once a procedure and format is agreed upon, there would be resource burdens to review, revise, and update existing permits. One strategy might be to "grandfather" new aspects into the existing permit process. For example, key technology could be inventoried and noted as an addendum to the permit. Signal timing could be approached in a similar manner. Another approach may be to separate technical aspects from legal aspects so that technical revisions can take place even if legal issues slow the revision process.

BARRIERS TO IMPLEMENTATION

Potential barriers to implementation include:

- Difficulty in garnering support for initiative from PennDOT Districts, municipalities, and legal counsels
- Inability to overcome resource constraints.

RISK CONSIDERATIONS

Possible risk considerations include:

- Failure to gain concurrence on permitting process.
- Failure in revising technical aspects due to legal issues.

7.6.4. Implementation Considerations

Traffic signal permitting is an ongoing practice. Therefore, the best approach may be to review the current process, identify technical revisions, and then identify legal revisions. It is unlikely it would be feasible to revise and update 13,600 permits; therefore, the revised permit should be applied to new installations or when revisions to existing permits are needed.

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

Key next steps include:

- Form an advisory committee consisting of representation from PennDOT Central Office, Districts, local municipalities, and respective legal counsels.
- Identify technical revisions and develop implementation plan
- Identify legal revisions and develop implementation plan.

7.7. ESTABLISH OPERATIONAL AUDITS PROGRAM

Several stakeholders cited that critical signal systems are not evaluated frequently enough due to the lack of data collection and the cost of analysis. Ideally, critical systems should be extensively evaluated every three to five years. An efficient and cost-effective procedure should be considered that periodically assesses critical systems in order to improve **operations**.

Several districts perform informal operational assessments of critical corridors on a periodic basis or when issues arise; however, no formal process or protocol exists for performing these assessments. Often these assessments are performed "when time permits" but not as part of an organized or systematic spot-audit process. Although minor improvements can be identified and made within this current process, other stakeholders are not made aware of these improvements and of the larger issues identified which may necessitate dedicated funding.

Guidelines and protocols for performing operational audits should be established so key stakeholders are involved/ aware of the process and as such can promote needed improvements. Specific considerations to be evaluated when conducting these audits are detailed in **Exhibit 7.11**. Stakeholder involvement is detailed in **Exhibit 7.12**.

Exhibit 7.11: Operational Audit – Assessment Considerations

Assessment Area	Considerations
Operations	➢ Are intersection phases appropriate for observed conditions? ➢ Are intersection timings appropriate for observed conditions? ➢ Is the intersection on the appropriate "recall" mode? ➢ Is there suitable progression between intersections?
Maintenance	➢ Are detectors functioning properly? ➢ Are individual signals interconnected and communicating properly? ➢ Are there any other maintenance issues?
Other	➢ Could lane reassignment or minor geometric enhancements improve operations? ➢ Could basic, low-cost access management practices (such as shared driveways) improve operations? ➢ Are emergency services needs addressed? ➢ Are pedestrians accommodated?

Where required, improvements can be validated through data collection and analysis along with the appropriate level of documentation.

Operational audits would be a low-cost mechanism to assess the technical expertise of municipal staffs and to provide pier-to-pier training through the operational audit process.

The level of implementation is dependent on the resources available and the level of operational cooperation of the involved stakeholders.

Operational audits could be set at a modest percentage by signal type. Findings should be broadly communicated and provide the basis for a more complete picture of the condition/performance of PA's traffic signals.

Exhibit 7.12: Operational Audit – Stakeholder's Role

	Stakeholder	Role in Operational Audit
Operational Audit Team	**Planning Organization**	➢ Copied on operational audit report ➢ Provide opportunity to participate
	PennDOT BHSTE	➢ Copied on operational audit report ➢ Provided opportunity to participate
	PennDOT Districts	➢ Coordinate and document operational audit ➢ Provide expertise
	Local Municipalities	➢ Local input
	Maintenance Provider	➢ Guidance on maintenance issues and needs
	Others, as required (EMS, transit, etc)	➢ Input on special needs/ issues

FHWA is completing an effort entitled: *Traffic Signal Timing on a Shoestring.* The effort will explore and document the minimal amount of data collection and optimization that should be performed in a signal retiming project to acquire some appreciable benefits.

7.7.1. Comparable Best Practices and Lessons Learned

Although there are no formal operational audit program documents identified in the research, several states have promoted road safety audits. Often, safety audits can yield improvements that improve safety and reduce congestion.

The Institute of Transportation Engineers and the Federal Highway Administration sponsor a Road Safety Audit website at www.roadwaysafetyaudits.org. This site lists the benefits of road safety audits to include recommendations that improve safety, promote awareness of best practices, integrate multimodal safety concerns, and consider a variety of design issues. Representatives from DOTs in South Carolina, Mississippi, Iowa, Missouri, Minnesota, and Pennsylvania attest to success in using road safety audits to implement improvements.[88]

An intersection in Grand Rapids, Michigan is highlighted as a best practice on the Road Safety Audit website. During an audit, it was determined that the traffic signals hanging on diagonal wire should be moved to a box span of wire so the signals would hang over the travel lanes.[89]

Audit: Before and After

7.7.2. Criteria Evaluation and Benefits

The scope of an audit may be designed to address a wide range of traffic signal issues. The audit team members and review topics are flexible and may be chosen to address the best in traffic signal design and safety. The audit team's recommendations can provide municipalities with a plan for improving their systems and working with neighboring municipalities. An audit is an effective way of introducing regional, national, and international best practices to the local level. The key to a successful audit is that the review is matched with a mechanism for implementing the recommendations. Another key is to start small and expand the audit effort over time as beneficial, and as resources permit.

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	Implementing audit recommendations can be effective in addressing delay
Intersection Operations	Positive	Implementing audit recommendations can be effective in addressing intersection operation
Crash Reduction	Positive	Implementing audit recommendations can be effective in creating safer corridors
Financial Savings	Positive	Increased personal mobility by lowering travel times. Reduced emissions due to congestion may lead to fewer health care problems (e.g. asthma)
Intermodalism	Positive	Implementing audit recommendations can be effective in intermodal connectivity including improved pedestrian accommodations
Public Perception	Positive	The best ideas in traffic design are being applied to their travel
Practical Feasibility	Positive	Low-cost program

7.7.3. Feasibility Assessment

The initial barriers implementing a traffic signal-specific review process may be increasing the staff required at the state level to conduct the reviews. This increase in human resources may be streamlined by adding traffic signal specific audit requirements to existing road safety audits. Once the audit is complete, municipalities will likely require additional resources to implement the audit's recommendations. Attaching funding streams to the audits would increase the likelihood that audits would result in successful traffic signal improvements. This may also lend itself to a well supervised intern person.

There has been concern that road safety audits would increase an agency's liability, however in practice, it has been found that by having a documented proactive plan for improving safety is a defense for tort liability.[90]

BARRIERS TO IMPLEMENTATION

Potential barriers to implementation include:

- Concern regarding the formalization of an informal process
- Human resource needs
- Funding for improvements

- Willingness to participate
- Misunderstanding of "audit" process, thinking it is an inspection with sanctions, etc.

RISK CONSIDERATIONS

Potential risk considerations include:

- Misunderstanding of roles and responsibilities in addressing audit recommendations

7.7.4. Implementation Considerations

Operational audits are an effective, low-cost way to identify signal system enhancements in the short-term.

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

- Develop basic (high-level) goals and guidelines for performing the audits.
- Develop guidance on attendees and those to be copied on audit results.
- Pilot initiative in several districts.

7.8. Complete Updates and Revisions to PennDOT Traffic Signal Publications

PennDOT publications and guidelines provide a vital tool for both PennDOT and local authorities in designing, constructing, maintaining, and operating signal systems. Signal systems involve a variety of disciplines and evolving technologies. Signal **training** and education can be divided into four core areas:

Educational materials should give guidance on the deployment of signal systems such as closed loop systems so all parties have a clear understanding of operational and maintenance responsibilities and so that technology implemented is utilized to its fullest extent.

Additionally, guidance should be given on the deployment of adaptive control strategies (ACS). ACS use algorithms that perform real-time optimization of traffic signals based on current conditions. As a result, system delays are reduced because the system reacts to existing conditions. Since the system is responsive in real-time, there is a reduced need for signal retiming initiatives. ACS have limited deployments in the United States due to system cost, complexity, and uncertainty of the benefits.

Operations – Operations include the assessment of traffic flow needs to consider the number and arrangement of lanes, phasing, and timing. Operations (such as phasing and timing) establish the basic parameters for signal design, but are also critical in reassessing existing operations.
Design – Design considers the physical layout of the signal installation. Such items as location and types of structures are considered as well as pedestrian accommodations and signal head placement. Design is contingent upon operational requirements.
System – Involves other disciplines to integrate communications and technologies in order to make the signal function properly and communicate with other signals and systems.
Maintenance – Includes preventive and response maintenance activities to keep signal systems operating efficiently.

PennDOT is currently updating several traffic signal publications. These publications should continue to be updated. Where deficiencies in PennDOT publications (**see Exhibit 7.13**) exist, national publications should be identified or additional materials should be developed.

Exhibit 7.13: PennDOT Traffic Signal Publications

Publication	Status	Material Covered
PennDOT Publication 148 Traffic Standards (TC-7800)	Released 1989 Update planned in 2005	Standard drawings for traffic signal design
PennDOT Publication 149 Traffic Signal Design Handbook	Released 1988 Update planned in 2005	Basic design, systems and operational guidance
PennDOT Publication 191 Guidelines for the Maintenance of Traffic Signal Systems.	Released 1989 On PennDOT's website	Basic guidelines on maintenance practices
PennDOT Publication 408 Roadway Specifications	Released 2003 Continual updates On PennDOT's website	Specifications for standard items

Publication 191, *Guidelines for the Maintenance of Traffic Signal Systems* should be updated. Future updates should include: updating standard maintenance contracts, an operational assessment checklist, and updated guidance on preventative and response maintenance activities.

TRAFFIC ENGINEERING AND OPERATIONS

3 Core Courses

- Transportation Management (0.6 CEUs)
- Incident and Emergency Management (0.8 CEUs)
- Traffic Signal Timing (0.8 CEUs)

Choose 2 Electives

- Advanced Signal Systems (0.8 CEUs)
- Corridor Management (1.4 CEUs)
- Dynamic Route Guidance and In-vehicle Systems (0.8 CEUs)
- Tools of Advanced Transportation Management Systems (0.8 CEUs)
- Traffic Flow Theory (0.8 CEUs)

Choose a Bonus Course

- Introduction to Intelligent Transportation Systems (0.4 CEUs)
- What's New in ITS (0.4 CEUs)

On-line courses available at www.citeconsortium.org

All key resources and their availability should be disseminated to key stakeholders at all levels. Where possible, publications should be made available in electronic format and/or via a website to reduce production and mailing cost. Distribution to municipalities should be coordinated through PennDOT's Municipal Services as well as organizations such as Local Technical Assistance Program (LTAP) and Pennsylvania State Association of Township Supervisors (PSATS).

PennDOT's Traffic Resources Education and Computing Support (TRECS) group should continue to assess educational and training needs.

Additionally, training opportunities such as the CITE On-line Transportation Course could be listed for prospective students within PennDOT, local municipalities, planning organizations, and private companies.

Currently, several PennDOT districts are participating in the CITE program, but other districts were unaware of this training opportunity.

7.8.1. Comparable Best Practices and Lessons Learned

A study for the US DOT, *Sharing Data for Public Information: Practices and Policies of Public Agencies*, describes how and why agencies share information. "Agencies share their data with the private sector and other agencies with two main objectives in mind: improving transportation operations through better interagency coordination and optimizing the use of the transportation system by providing information to travelers."[91]

Traffic signal specific publications are available on many state Department of Transportation websites. New York DOT lists several publications in an on-line library that includes the approved list for traffic signal hardware.[92] New Jersey DOT has a database that site users may use to search 210 on-line documents; two documents are found searching *traffic signals*.[93] Ohio Department of Transportation hosts the Design Reference Resource Center where users may find resources related to traffic signals and subscribe to select publications, and are notified when updated documents are available.[94]

7.8.2. Criteria Evaluation and Benefits

Providing updated publications on the PennDOT website may be an effective way of promoting regional coordination. Local agencies may use the website as a resource for local and regional planning efforts. Creating an environment where information is readily shared may be an effective first step to fostering corporative planning efforts. The shared research could facilitate planning to effectively use and coordinate traffic signals.

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Limited	Ideas implemented from publications may reduce delay
Intersection Operations	Limited	Ideas implemented from publications may improve intersections
Crash Reduction	Limited	Ideas implemented from publications may reduce crashes
Financial Savings	Limited	Ideas implemented from publications may save money in operation costs and increased efficiency
Intermodalism	Limited	Ideas implemented from publications may increase connectivity
Public Perception	Positive	Sharing information fosters a cooperative working environment with local government and public
Practical Feasibility	Positive	Electronic publication could be easily located on PennDOT website

7.8.3. Feasibility Assessment

Increased staff time and computer server capabilities would be likely start up costs for an expanded website. The liability of how the data is used may be addressed by using a disclaimer to access the data.

BARRIERS TO IMPLEMENTATION

Possible barriers to implementation include:

- Need to allocate resources to update and develop new criteria.

RISK CONSIDERATIONS

Risk considerations are limited.

7.8.4. Implementation Considerations

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

- Identify areas of deficiencies
- Update existing materials
- Develop methodology to distribute training and education opportunities and resources
- Promote a more dynamic sharing and updating of information similar to the other states described above.

7.9. ALLOCATE A PORTION OF ANY NEW FUNDING INCREASE TO SIGNALS

Chapter 90 of Title 75 (The Vehicle Code) of the Pennsylvania Consolidated Statutes enables the collection and distribution of the liquid fuels tax, a permanent state tax of 12 cents per gallon (**see Exhibit 7.14**). One-half cent per gallon of that tax is paid into a liquid fuels tax fund specifically appropriated for transportation improvements, one of which is traffic signals, including acquisition, maintenance, repair, and operations.

Exhibit 7.14: Funding Statistics

Tax	Approximate Amount Sold in PA in 2002-2003 (gallons)	Current Tax Rate	Approximate Revenue Generated (2002-2003)	Approximate TOTAL Revenue generated w/ 1 Cent Increase	Approximate TOTAL Revenue generated w/ 3 Cent Increase
Retail Gas Tax	5,033,000,000	12 cents/gallon	$604 million	$654 million ($50 million increase)	$755 million ($151 million increase
Retail Diesel Tax	1,292,000,000	12 cents/gallon	$155 million	$168 million ($13 million increase	$194 million ($39 million increase

Another funding consideration may the use of revenues generated from Automated Red-light Enforcement (ARLE) if legislation is adopted to permit their use beyond the current deployments in Philadelphia.

Based on figures presented in **Section 2**, it is estimated that basic maintenance and utility service for Pennsylvania's 13,600 traffic signals with an asset value of approximately $1 billion costs between $38 and $50 million per year. This does not include basic operational oversight (estimated at $20 -$40 million/ year) and signal enhancements (variable). An initial estimate of $100-150 million dollars annually is needed to sufficiently maintain, efficiently operate, enhance existing systems as well as for review of technology, operations management and deploying new systems.

Almost every transportation agency, including PennDOT, identifies inadequate **funding** for transportation projects as a major concern. In this case, funds for the enhanced support of traffic signal operations and maintenance are the driving factor behind this solution. Currently, traffic signal system projects are funded through highway portions of transportation dollars. As expected, these funds rarely filter down to these projects due to the high level of awareness of bridge and highway projects. TAC believes that a dedicated funding source for traffic signal systems is needed. These funds could be applied to the operations as well as maintenance of the systems. TAC is recommending that a portion of any new funding source be allocated for signal systems operations and maintenance (**see Exhibit 7.15**); i.e. an increase in the gasoline tax. The operations and maintenance of intelligent transportation systems should also be considered, but was not the focus of this study.

Exhibit 7.15: Possible Increased Funding Distribution Considerations

Distribution	Estimated Funding %	Distribution Considerations
Planning Organization	2	➢ Planning and programming ➢ Coordination of Regional Traffic Signal Improvement Program
PennDOT BHSTE	10	➢ Development of training and education ➢ Statewide asset management ➢ Implementation of technology ➢ Coordination of Statewide Signal Committee
PennDOT Districts	43	➢ Signal warrant analysis ➢ Design under certain conditions ➢ Operations of some signal systems (critical corridors) ➢ Coordination of Critical Corridor Consortiums ➢ Operational oversight/ evaluation of signal systems ➢ Traffic Management Center (TMC) integration with signal systems ➢ Asset management of systems
Local Municipalities	43	➢ Design under certain condtions ➢ Operations of some signal systems ➢ Incentive programs (see sections 7.11-7.13) ➢ Utility services ➢ Maintenance activities
Others	2	➢ Emergency preemption enhancements ➢ Transit priority systems

The Commonwealth should also consider a legislative change that would automatically index fuel taxes and license/ registration fees to a standard inflation rate, such as the consumer price index. This measure would allow motor license fund revenues to grow at the same rate of inflation. This index approach should be closely tied to a comprehensive asset management system approach (previous recommendation) that would help ensure that funds are being used effectively and are addressing the most pressing needs. This broader recommendation is made here since the cost of traffic operations, like other transportation features, increases year to year.

7.9.1. Comparable Best Practices and Lessons Learned

New funding could potentially result from a redistribution of federal gas tax revenue. Oftentimes, metropolitan areas receive pennies on the dollar from gas taxes. The Environmental Working Group compared gas tax payments to gas tax revenues for metropolitan regions and found several areas are losing significant tax revenue, particularly in southeastern Pennsylvania.

While these losses stem from federal tax dollars, this misallocation can have ramifications for signal systems, particularly if signal systems are not high priority issues in these regions. It therefore may require specific earmarked state funding in order to ensure signal systems are adequately maintained and operated.

Unfortunately, research into other state's signal funding found little evidence of such earmarked signal funding to use as best practices. Of the 14 states surveyed, none had a specific earmarked funding source for signal systems. Oftentimes, signal systems are funded from the general operating and capital budgets. Allocating new funding specifically to signals would likely be an innovative funding practice.

Vancouver's 2003 Traffic Signal Program earmarks funding for both capital improvements and operating budgets, providing a future stream of operating revenue after capital projects are completed[95]. While the funding allocation is small ($20,000 Canadian), it ensures capital improvements will have a specified source of operations funding. In Springfield, Missouri a 1/8th cent sales tax has been in place since 1996 that earmarks a portion of the generated revenues to an Intelligent Transportation System that includes traffic signal operations[96]. Decatur, Illinois uses a portion of the Motor Fuels Tax Fund to pay for maintenance and operations, though it is unclear as to whether a percentage of the tax or a fixed sum is earmarked for traffic signals.

7.9.2. Criteria Evaluation and Benefits

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Improved	Increased funding will be directed in part to operations
Intersection Operations	Improved	Increased funding will be directed in part to operations
Crash Reduction	Improved	Funding should also address major safety concerns at signalized intersections
Financial Savings	Negative	Savings may come in the long-term from improved system, but short-term impacts are clear.
Intermodalism	Improved	Improved pedestrian and transit
Public Perception	Neutral	The public generally supports funding for transportation, but the timing of increases relative to gas prices is a real consideration.
Practical Feasibility	Unknown	Other states have increased gas taxes over the last couple of years

7.9.3. Feasibility Assessment

Perhaps the greatest barrier to implementation of this solution is the financial feasibility. As of 2002, Pennsylvania had the 11th highest gasoline tax in the U.S[97], which may make tax increases difficult. Additionally, gas tax increases are occasionally considered more onerous than other taxes. One example is a Lake County, Illinois poll that found residents were more amenable to a sales tax increase than gasoline tax increase[98]. However, a Seattle, Washington poll found that a county-level gas tax was considered more preferable than either a parking tax or property tax[99].

Other states are increasing their gasoline tax to keep up with inflation. The first 2 cents of a 6-cent-a-gallon gas tax being phased in over three years went into effect the summer of 2003 in Ohio. This will raise the state's tax to 28 cents by 2005. Another example is Washington State. Washington Governor Gary Locke signed a 5-cent-a-gallon gas tax into law May 20, 2003 increasing the state gas tax to 28 cents as of July 1, 2003.

Barriers to Implementation

Increasing a tax is always politically challenging with regards to the public. PennDOT will need to convince the legislature that an increase in the gasoline tax or creation of a new funding stream is necessary.

It is believed that local and regional governments will be amenable to this idea because it provides more money for their transportation projects especially traffic signal projects.

Risk Considerations

Potential risks for this recommendation include:

- It will require legislative action.
- For bond-financing, a steady funding source is not available to pay off the debt, which in-turn over extends PennDOT and increases the debt.

7.9.4. Implementation Considerations

This recommendation is dependent on legislative action. The time frame of this recommendation will depend on how quickly legislation is adopted.

If a new funding allocation is not achievable, the feasibility of allocation revisions to the existing funding structure to better address operations is not promising. Money is not often earmarked to specific transportation expenditures like signal systems, thus making it difficult to reallocate funding for signals without doing the same for other purposes. A 1996 study by PennDOT's Local Government Transportation Finance Task Force found that there was little reason to believe that a revision to liquid fuels revenue allocation would be politically possible[100]. The study recommended no change to allocation. It is reasonable to presume that these findings are still applicable.

Recommended Next Steps and Pilot Opportunities

- Identify funding needs and program opportunities with regard to signal systems and strategically promote signal funding.
- Consider an approach that entails a phased in funding approach if this is more feasible and politically palatable.

7.10. PROVIDE INCENTIVES FOR OPERATIONAL ENHANCEMENTS

Presently, there are no direct incentives for **operational** enhancements; therefore, municipal practices focus almost entirely on maintenance activities in order to be compliant with the traffic signal permit and to avoid liability issues. Operational enhancements have indirect benefits of reducing congestion, but no direct benefits to municipalities. Often operational enhancements are identified only when there are significant complaints by the public and/ or elected officials or as part of area development.

If additional funding is secured, financial incentives should be given to municipalities for implementing operational enhancements. Financial incentives should be used to encourage municipalities to invest in proactive monitoring, operating, and managing of their traffic signal systems. Often, these enhancements can be implemented at relatively low-cost.

Typical operational enhancements may include:

- Lane reassignment or minor geometric enhancement
- Repairing detectors
- Assessing and adjusting modes of operation
- Adjusting timing and offset to improve intersection operations and corridor progression
- Development of new timing plans and timing plans to address special needs such as homeland security, incident management and special events
- Installing compatible technologies such as the same type of controller
- Upgrading communication systems
- Implementation of energy saving devices such as Light Emitting Diodes (LEDs)
- Addressing emergency service needs.

The incentive should cover a percentage of the evaluation, design and implementation of the enhancement provided these benefits could be documented. The exact percentage of incentive should be further evaluated to determine an appropriate level that encourages municipal participation, but does not result in unlimited requests.

7.10.1. Comparable Best Practices and Lessons Learned

Financial incentives should be of the magnitude to influence the decision making of municipal officials regarding traffic signal operations. Rather than create government mandates to adhere to certain policies, this approach would be more market driven to let each municipality decide for itself whether to strive to achieve them. An example of this market-based approach can be found in the incentive programs for intermodal transport development in Germany and the Netherlands. The basis of these programs is to let each individual city or region decide what is feasible, while the respective governments provide financial incentives to develop intermodal terminals and logistics support.[101]

The Sacramento Municipal Utility District found success in motivating local jurisdictions to convert traffic signals from incandescent lamps to light emitting diodes by providing rebates of about $225 for each on-peak kilowatt that they reduce. The city and county of Sacramento and the cities of Citrus Heights, Folsom and Elk Grove participated in this successful incentive base program.[102]

Financial incentives may be in the form of low or interest free loans, grants or matching funds. Models for providing financial incentives are PENNVEST, Community Development Block Grants, and open space funding mechanisms. In addition, Pennsylvania's Growing Smarter Program provides financial incentives for joint municipal comprehensive planning. The Governor's Center for Local Government Services, which administers the program, funds up to 50% of an approved application, to a limit of $100,000 a year.[103]

7.10.2. Criteria Evaluation and Benefits

Incentives for operational enhancements will cultivate an environment that encourages initiative, creativity, and opportunity. Incentives will provide the proverbial "carrot" to municipalities in order to facilitate flexible problem solving in the undertaking of operational enhancements at the local level. Inefficiency and waste can be reduced as municipalities strive to meet established operational benchmarks.

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	Decrease delays and travel time
Intersection Operations	Positive	Improves traffic flow; safer intersections
Crash Reduction	Positive	Crashes reduced due up to date operations
Financial Savings	Negative	Economic based savings (increased efficiency); reduced air quality problems
Intermodalism	Positive	May lessen conflict points with trucks
Public Perception	Positive	Provides public with a mechanism to hold agencies accountable for traffic signal operations and enhancements
Practical Feasibility	Unknown	

7.10.3. Feasibility Assessment

By providing financial incentives, it may be difficult for some municipalities to remain objective in trying to attain the operational benchmarks. In situations that require municipalities to balance the interests of the entire transportation system with those of traffic signal systems, municipalities may be prevented from carrying out their fundamental obligation of the public interest as a whole. Moreover, municipalities may seek to meet operational benchmarks on a one time only basis with no established rationale in relation to continuous monitoring or operational upkeep. This is why the audit recommendation has merit in relation to this incentives approach.

BARRIERS TO IMPLEMENTATION

Potential barriers to implementation include:

- Inability to acquire additional funding for the program
- Municipal resentment over "carrot-and-stick" approach

- Failure to develop successful evaluation criteria.

RISK CONSIDERATIONS

Potential risk considerations include:

- Lack of compliance with program criteria may result in poor application of resources.

7.10.4. Implementation Considerations

This initiative is contingent on the acquisition of additional funding for signal systems operations, maintenance, and enhancement. There is a need to reward good performance and not just for complying with the permit.

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

- Monitor funding climate.
- Develop "fair" program guidelines.
- Tie to operational audits and municipalities' willingness to make continued improvements.
- Identify pilot opportunities to test without funding or with another limited funding source such as the IDEA program.

7.11. Encourage Regional Maintenance Contracts with Operational Incentives

Shared maintenance across jurisdictional boundaries provides an opportunity to decrease contract costs through improved economies of scale and to improve **operations** through better coordination and communication, as well as through operational incentives to maintenance contractors. It also reduces the amount of training needed for each municipality. PA has a large challenge achieving local government efficiency with so many units of municipal government. There is a great interest in cooperation and collaboration, recognizing that may be more feasible/practical than mergers.

Shared maintenance contracts provide an opportunity to share resources, thus reducing costs. Shared maintenance practices are most beneficial in rural areas, where limited ownership of signal systems may result in higher per signal maintenance costs. As part of the update (**Section 7.8**) to PennDOT Publication 191, *Guidelines for the Maintenance of Traffic Signal Systems,* the existing standard shared maintenance and regional maintenance contracts should be revised and updated to be used by municipalities and regional consortiums. Critical components of shared maintenance contracts include:

- Defining roles and responsibilities
- Defining reporting and financial protocols
- Defining response maintenance activities and response times
- Defining preventive maintenance requirements and timeframes
- Defining operational requirements
- Identifying incentives.

The operational incentive program discussed in **Section 7.10** should be extended to maintenance contractors. Often, maintenance contractors are aware of operational deficiencies, but have no mechanisms to make enhancements. Funding increases discussed in **Section 9** would be used for incentive part of this recommendation.

Examples of Deficiencies in Current Maintenance Practices

- A maintenance contractor may note that an operational enhancement may be beneficial when performing routine maintenance, but neither the contractor nor municipality may be able make the improvement due to limited resources.
- A maintenance contractor who supports two neighboring municipalities may not have any mechanism or incentive to make an interjurisdictional enhancement that benefits an entire corridor

7.11.1. Comparable Best Practices and Lessons Learned

Regional maintenance and coordination for traffic signals can be effective in creating transportation corridors with reduced delay and travel time while providing a cost saving to participating jurisdictions. Consolidating resources can provide jurisdictions with technology improvements they could not afford on their own. Also, MPOs/RPOs have had success in using access to funding as an incentive for participation in a project.[104]

In the City of Tucson, Arizona the Department of Transportation's Traffic Control Center supports the Advanced Transportation Management System for over 400 traffic signals for 7 jurisdictions within the greater Tucson region. While the central server for signal coordination resides with Tuscon, the individual agencies maintain responsibility for field maintenance. The regional coordination is effective in reducing network delay and travel time and the participating agencies save total operation costs by pooling resources. Cost saving is an incentive for participating.[105]

Operation Green Light is a regional traffic signal coordination effort led by the Mid-America Regional Council for the greater Kansas City, Missouri area. The project set forth to improve cooperative relationships, upgrade technology and equipment, create effective communication networks, and develop and deploy signal timing plans. The 56.8 million dollar project will connect the signal programming for 17 jurisdictions. The anticipated benefits include savings to the local economy in fuel and time spent in congested traffic and decreased air pollution.[106]

7.11.2. Criteria Evaluation and Benefits

Regional maintenance and coordination for traffic signals can be effective in reducing travel time. Improving the traffic flow benefits the economy by reducing fuel and time costs and improving intermodal connectivity. The incentives for a jurisdiction to participate in a regional coordination effort include access to technology they could not afford on their own, improved traffic flow on multi-jurisdictional corridors, access to funding streams reserved for regional planning efforts, and cost savings in sharing operational costs between jurisdictions. These cost saving and technology enhancing incentives appear to be great enough to foster participation; no examples were found where jurisdictions were paid to participate in meetings.

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	Traffic flow between jurisdictions is improved
Intersection Operations	Positive	Congestion from one jurisdiction is less likely to exist and overflow into another
Crash Reduction	Positive	
Financial Savings	Positive	Traffic flow between jurisdictions is improved
Intermodalism	Positive	Jurisdictions without some modes of transportation can plan for connectivity through other jurisdictions when they work together
Public Perception	Positive	Cooperative government working in their best interest
Practical Feasibility	Positive	Several examples in Pennsylvania

7.11.3. Feasibility Assessment

Several stakeholders noted there are some limited examples of shared maintenance programs within Pennsylvania. Since shared maintenance (without incentives) could be implemented in the current climate, it is concluded this initiative is highly feasible and would be more widely supported if guidance and operational incentives were provided.

BARRIERS TO IMPLEMENTATION

Potential barriers to implementation include:

- Reluctance by neighboring municipalities to cooperate for fearing of increased costs.
- There is a need for at least one municipality to take a leadership role in establishing the program.
- There may be a disagreement regarding "fair" share contributions.
- Some municipalities may have different technologies which may hamper a regional approach.

RISK CONSIDERATIONS

None identified.

7.11.4. Implementation Considerations

The update to Publication 191 and new funding allocations should be considered when pursuing this initiative.

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

- Develop and include standard shared maintenance contracts in Publication 191 update.
- Monitor funding climate.

7.12. PROVIDE INCENTIVES FOR INTERJURISDICTIONAL COORDINATION

Interjurisdictional coordination is often an objective in long-range transportation plans. This type of coordination can help promote a regional, as well as a **holistic** system approach to managing and maintaining traffic signal systems. As part of this recommendation, funding preferences would be given to projects that are requested using collaborative funds by collaborative efforts. The approach would encourage MPOs/RPOs, counties, and other jurisdictions to work closely together and to think beyond their political boundaries. This initiative is consistent with the ideas presented in **Section 7.2**, but provides financial incentives to implement interjurisdictional coordination. Part of the inter-jurisdictional coordination should include integration with regional traffic management centers (TMCs) to address regional traffic and operations.

Many municipalities do not have the expertise, staff or funding to operate and maintain their traffic signal systems to their full potential. However, if traffic signal partnerships were formed, the burden would be shared by many. As a part of the traffic signal partnerships, funding incentives could be offered for doing so.

This recommendation is one that should be carried out in balance so that it does leverage transportation resources, but at the same time does not result in an oppressive degree of "strings attached." Transportation resources are substantial and should result, where practicable, in other beneficial activity by the recipient that contributes to the overall operation and maintenance of traffic signal systems as well as the transportation system as a whole.

Incentive programs will need to meet the needs of both the Department as well as the recipient. An example program may be as such:

- One time allocation of funds provided for upgrade of a signal system to municipalities who work together.
- Once upgraded, these municipalities must continue to maintain the systems to a certain standard. The Department will regularly monitor the system to ensure that the conditions are being met. In return for proper maintenance of the signal systems, the municipalities will receive a cost incentive fixed sum that can be used for transportation improvements.

7.12.1. Comparable Best Practices and Lessons Learned

Few practices exist that are directly applicable, but the Mid-America Regional Council's Operation Green Light project has done similar research that may prove valuable. Houston's TranStar combines transit agencies from Houston and the surrounding areas, utilizing as their headquarters a central control site estimated to cost over $13 million. While each agency contributes to operating cost on a prorated basis, no mention is made of the headquarters' funding. It is possible that Texas Department of Transportation aided in the funding of this building. In Nevada, the Las Vegas Area Computer Traffic System (LVACTS) gets staffing and equipment support from Nevada DOT and the headquarters are sited in NVDOT right-of-way[107].

On a national scale, the ITS Metropolitan Model Deployment Initiative began in 1996 with the goal of creating a nationwide ITS network. The metropolitan model deployment projects are a success in part because they are public-private partnerships, where a full 50% of total project cost is provided by private corporations[108].

Another example of interjurisdictional incentive programs is that of the Salt Lake City Region. The MPO in this area has indicated there will be preference for limited ITS funds to be awarded to multi-agency teams. Because of this preference, it has become common practice for the Utah DOT, the Utah Transit Agency, and individual cities to routinely submit joint applications for funding of projects. This has streamlined the process for the Salt Lake City Region, and has ultimately reduced the staff time and effort needed for selecting projects for funding.

7.12.2. Criteria Evaluation and Benefits

Projected positive impacts included reduced network delay and travel time, improved intersection operations and practical feasibility. Financial savings are likely to be minimal since decreased costs to the state in long-term transportation benefits should be offset by short-term incentives to other communities.

Criteria	Estimated Impact	Notes
Network Delay and Travel Time	Positive	Long-term network efficiency is the overriding purpose of this solution
Intersection Operations	Positive	As mentioned earlier, coordination will reduce lag time in repairing system problems
Crash Reduction	None	
Financial Savings	Minimal	Short-term loss due to incentive provision, but in the long-term most of that money should be made back in the form of increased network efficiency
Intermodalism	None	
Public Perception	Unknown	No data found on public perception of these projects
Practical Feasibility	Positive	Several communities have shown different methods for making this solution work

7.12.3. Feasibility Assessment

Such projects are feasible, particularly when the private sector plays a role in the funding of interjurisdictional efforts. Additionally, if new funding sources were dedicated to signal systems, such incentives would be more easily provided.

BARRIERS TO IMPLEMENTATION

Potential Barriers to Implementation include:

- Inability to determine a funding source to implement these incentives.

RISK CONSIDERATIONS

None identified

7.12.4. Implementation Considerations

RECOMMENDED NEXT STEPS AND PILOT OPPORTUNITIES

This recommendation will be highly dependent upon whether funding is available for such programs. However, municipalities should view this as a favorable strategy.

8. OTHER POTENTIAL SOLUTIONS

In addition to the recommendations detailed in **Section 7**, many other potential solutions could provide short-term, as well as long-term improvements for the operations and maintenance of traffic signal systems. The following tables present Tier II through IV potential solutions, the benefits of each, and recommended implementation steps. Tier II, III and IV solutions are potential solutions that were not evaluated in detail.

8.1. TIER II PRIORITY POTENTIAL SOLUTIONS

Exhibit 8.1: Tier II Priority Potential Solutions

Solution/ Idea	Description	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Category	Benefits
Evaluate and pilot an AGILITY approach to operations and maintenance	➢ The AGILITY program provides a mechanism for exchange of services for municipalities and PennDOT ➢ The overall concept would be for PennDOT to assume ownership of signals in lieu of other services ➢ The barriers may be the fact that PennDOT does not currently have maintenance capabilities for signal systems; therefore, this would be a new service area or would require contract services	Short	Holistic	➢ May improve signal operation and maintenance in cases where PennDOT has more technical expertise
Inventory existing signal systems as part of an asset management system and in order to identify system needs and deficiencies	➢ Conduct inventory of traffic signals statewide, and identify all deficiencies. Catalog all known signals, including location, condition, equipment, maintenance, system integration, etc. (see Minnesota's Maintenance Management System)	Medium	Holistic	➢ Inventory of signals can ensure timely maintenance, reducing likelihood of serious signal problems ➢ Performance Measures that PennDOT can use to track traffic signal projects, upgrades, maintenance etc.
Develop a strategic plan for signal system deployment, maintenance and operations	➢ Create and implement a 20-year strategic plan for traffic signals utilizing asset management tool and based on statewide summit	Short/ Medium	Holistic	➢ Formalizes a long-term strategy for improving signal systems that has statewide buy-in ➢ Provides a clear direction for the future of traffic signal systems in the Commonwealth

Exhibit 8.1: Tier II Priority Potential Solutions

Solution/ Idea	Description	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Category	Benefits
Develop "standard" scopes of work for maintenance and operations and "standard" specifications for traffic signal equipment	➢ Create a PennDOT-approved work procedure for common maintenance and operations work. Also include innovative contracts for incentive programs as well as shared maintenance activities ➢ Provide standard specifications for signal technologies for use by PennDOT but also municipalities ➢ This information should be available to all agencies that own, maintain or operate signals	Short	Policy and Planning	➢ May help smaller communities deal with maintenance and operations, and provide contractors with standard procedures ➢ May provide better consistency and quality in the products deployed
Reevaluate DOT organizational structure at District and C.O. to address "Operations" as they relate to signal systems and ITS	➢ PennDOT is currently evaluating traffic engineering organizational structure at District level ➢ PennDOT is developing Transportation System Operations Plan which will provide more focus on "Operations" ➢ VDOT recently created "Operations" Division at an equivalent level with Maintenance or Design	Short/ Long	Policy and Planning	➢ Makes operations a critical component of transportation planning ➢ If developed properly, promotes traffic (and signal systems) as more desirable career track
As part pf permit revision or alone, consider the statewide implementation of a "systems" permit	➢ Create a new statewide signal systems permit such as the one used in District 6 ➢ Requires that changes to any part of a system require review and acceptance	Short	Institutional Responsibility/ Accountability	➢ Systems permit would ensure signal systems are evaluated as a whole entity and that changes are not made at an individual location without considering the entire system. ➢ Forces developers and PennDOT to think system-wide. ➢ Increases effectiveness of traffic signal systems

Exhibit 8.1: Tier II Priority Potential Solutions

Solution/ Idea	Description	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Category	Benefits
With or without a revision to the permit process, streamline timing modification process	➢ Allow some operational flexibility and allow for timing plan review and acceptance through electronic submittal or through connected systems. Ultimately, integrate in an asset management system	Short	Operations and Management	➢ Reduces delay in timing modification and help in interjurisdictional cooperation ➢ Reduces paper ➢ Reduces cost by eliminating postage, data entry etc. ➢ Already electronic, and can be easily incorporated into the asset management system
Revise HOP process to address corridors or signal systems and not specific signals only	➢ Provide clear and consistent guidelines as to developer responsibilities with regard to signal systems ➢ Current practice varies somewhat by District	Short	Operations and Management	➢ Requires new signal installation projects to consider the entire traffic signal system ➢ Provides better timing of traffic signals
Revise HOP process to require signal fine-tuning through road bonds and/or escrow	➢ Many signal retiming projects as part of development include implementation of new timings, but often system fine-tuning in the field is overlooked ➢ This solution would hold funds through performance bonds and escrow and require that the developer work with municipalities to address fine-tuning issues	Short	Operations and Management	➢ Delay and congestion will be reduced since timings will be adjusted to reflect actual field conditions rather than projected conditions ➢ Some of the financial burden of the municipalities may be offset by developers
Create modernization/ controller replacement program and interconnection programs	➢ Provide a program to upgrade controllers along a signal system to compatible technologies	Short/Long	Operations and Management	➢ Aids in streamlining of operations and maintenance ➢ Provides better compatibility between signaled intersections ➢ Increases safety ➢ Reduces congestion by promoting better traffic progression through corridors

Exhibit 8.1: Tier II Priority Potential Solutions

Solution/ Idea	Description	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Category	Benefits
Establish framework partnerships for the timely testing and implementation of new and existing technologies that are not yet used in PA	➢ Encourage public and private sector partnerships for new traffic signal technologies	Short	Technology	➢ Speeds incorporation of advanced technologies without undue financial burden on the public sector ➢ Keeps PA involved and up-to-date on state of the art technology and traffic signal equipment

8.2. Tier III Priority Potential Solutions

Exhibit 8.2: Tier III Priority Potential Solutions

Solution/ Idea	Description	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Category	Benefits
As part of the "holistic" management approach, produce and annual report on the "State of Signal Systems" as part of planning process	➢ Create and disseminate a summary and annual report on the state of traffic signals. Use a similar style to the Crash Facts and Statistics Report. Use this to help plan and guide resource allocation in relation to need.	Short	Institutional Responsibility/ Accountability	➢ Provides PennDOT with a "performance measurement" to gauge the progress of traffic signal projects ➢ Identifies where project emphasis is needed
Require timing plan development for homeland security/ incident / special event	➢ Establish signal timing plans through traffic management centers to address homeland security, incident & special event management, and emergency vehicle preemption ➢ Involve emergency management personnel in signal management system, as in Houston, TX	Medium	Operations and Management	➢ Improves traffic flow under special conditions
Encourage/ require emergency preemption and promote transit priority where applicable	➢ Retrofit existing signals to allow for emergency preemption and require new signal installations to have emergency preemption capabilities	Medium	Operations and Management	➢ Emergency vehicle response times are increased ➢ Safely allows emergency vehicles to move through intersections

Exhibit 8.2: Tier III Priority Potential Solutions

Solution/ Idea	Description	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Category	Benefits
Review sole source restrictions or consider innovative procurement methods to ensure "compatible" technology along key corridors	➢ Review current practice where 75% of the existing equipment must be of a particular make to specify that make ➢ Identify innovative methods to give the municipalities the equipment they want	Short/Long	Operations and Management	➢ Promotes goodwill between state and local municipalities ➢ Ensures that municipalities are utilizing compatible technologies thus improving traffic flow
Establish high level training for MPO/RPO's & stakeholders	➢ Create a half-day overview of traffic signal funding, ownership, maintenance and operation	Short	Training and Expertise	➢ Provides a basic understanding of traffic signal systems ➢ Allows regional leaders and stakeholders to make better informed decisions with regards to traffic signal systems
Create Traffic Signal Academy: Regional/ yearly interagency training for technical staff - PSATS, LTAP, PennDOT, local and private	➢ Create an intensive traffic signal training course focusing upon maintenance and operations	Medium	Training and Expertise	➢ Keeps technical staff up-to-date with new technology ➢ Allows for information sharing and networking of technical staff ➢ Give technical staff hands on training that is greatly needed
Encourage more vendor based training	➢ Consider allowing vendors to provide training ➢ Requires legal review	Short	Training and Expertise	➢ Vendors are often those who are more familiar with how equipment works ➢ Increases relationships with PennDOT and various vendors ➢ Increases PennDOT staff knowledge of how traffic signal equipment works and the maintenance required ➢ Provides competitiveness among vendors
Establish levels and tracks of training	➢ Create a standardized approach to operations division's training and career advancement	Long	Training and Expertise	➢ Provides opportunities for junior level staff to advance in their careers without leaving their current PennDOT office or section

Exhibit 8.2: Tier III Priority Potential Solutions

Solution/ Idea	Description	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Category	Benefits
Promote technology evaluations through universities	➢ Encourage increased utilization of PTI as a traffic signal technology research and testing center ➢ Consider installing test signals at university research facilities for testing purposes	Short	Technology	➢ Provides unbiased research into new technologies and incorporates the academic community into signal systems management
Encourage MPO/RPO funding category for maintenance and operations	➢ Ensure traffic signal maintenance and operations are a line item in MPO/RPO work programs. Encourage districts to advocate for inclusion of traffic signal maintenance and operations	Short	Funding	➢ Keeps funding for operations and maintenance at the forefront of transportation planning
Investigate utility-sponsored light emitting diode (LED) enhancement program	➢ Encourage coordination between municipalities and utility companies regarding LEDs ➢ In Maine, utilities and state partnered	Short	Funding	➢ Substantial energy savings ➢ California study found 40% savings in energy costs

8.3. Tier IV Priority Potential Solutions

Exhibit 8.3: Tier IV Priority Potential Solutions

Solution/ Idea	Description	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Category	Benefits
Host a statewide signal system summit as the first step in developing a strategic plan	➢ Convene statewide conference of traffic signal policymakers, local government engineers, and vendors	Short	Holistic	➢ Engages important stakeholders early in the planning process
Encourage retention within District Traffic Signal Units	➢ Many units have lost staff to other Departments or private companies ➢ Identify retention strategies and career tracks	Short	Policy and Planning	➢ Maintains a consistent group of signal experts who can aid in training and provide advanced assistance.

Exhibit 8.3: Tier IV Priority Potential Solutions

Solution/ Idea	Description	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Category	Benefits
Establish hotline/ website for traffic signal concerns and questions	➢ Similar (or expansion) of 1-800-Fix-Road	Short	Operations and Management/	➢ Reduces burden on other agencies who currently deal with these questions, and can be connected to asset management database
Develop an operations toolbox for municipal, regional and PennDOT usage	➢ Create a toolbox of innovative ideas, solutions, and operational tools for traffic engineers to pull from ➢ Toolbox should address "types of systems", "benefits" and "operational requirements"	Short	Training and Expertise	➢ Helps smaller communities to implement better traffic solutions
Establish PennDOT Bureau of Highway Safety and Traffic Engineering (BHSTE) technology analyst position for both signal systems and ITS	➢ A dedicated staff for signal systems and ITS that can act as a liaison between PennDOT and other agencies that deal with signal systems	Long	Technology	➢ Promotes quicker evaluation and deployment of technologies
Develop technology agreement package for municipalities willing to implement and test new technologies	➢ Agreement should address funding, liability and before and after studies	Short	Technology	➢ In conjunction with university testing, this could help make Pennsylvania a leader in signal innovation and implementation
Implement a developer impact fee approach for operations and maintenance	➢ Require developers to fund operations and maintenance of traffic signals on affected corridors	Long	Funding	➢ Will reduce public financial burden
Strategic use of impact fees and transportation partnerships for funding the improvement of signals	➢ Encourage municipalities to use impact fees and assessments for the installation, maintenance and operation of signals	Short	Funding	➢ Reduced public financial burden
Explore solar powered signals as a research topic	➢ Solar as an alternative/ supplement to utility powered signals	Short	Funding	➢ Energy savings

9. RECOMMENDED RESOURCE CONSIDERATIONS

This report has offered a range of recommendations for consideration by the Secretary and the State Transportation Commission. This section provides a synoptic summary of the higher tier solutions along with preliminary identification of resource requirements (**see Exhibit 9.1**). In addition, the benefits for any such investment are noted for critical contextual comparison to the cost issues.

Exhibit 9.1: Recommended Resource Considerations

Solution	Resource Requirements	Resource Benefits
1. Develop of an Asset Management System	➢ Funding for development of software ➢ IT support ➢ Establishing the initial inventory ➢ System maintenance	➢ Increased staff efficiency in planning, operations and maintenance of signal systems by all stakeholders ➢ Ensuring that programs, projects and services are delivered in the most cost effective way possible
2. Pursue Tiered Operations and Maintenance on Critical Corridors	➢ Need to identify critical corridors ➢ Increased coordination activities ➢ More operational responsibility (may require 24/7 role)	➢ May limit redundant activities occurring currently ➢ System efficiency increases
3. Pursue Tiered Operations and Maintenance for most Signals	➢ Increased coordination activities ➢ More operational responsibility ➢ Increased planning organization involvement	➢ May limit redundant activities occurring currently ➢ System efficiency increases
4. Promote a "Holistic" Approach to Signal Management	➢ Increased coordination activities ➢ Development time/effort	➢ A significant existing gap would be closed with respect to the overall management of this infrastructure and its potential improvement for congestion reduction.
5. Expand Traffic Signal Enhancement Initiative (TSEI) and Congested Corridor Improvement Program (CCIP)	➢ Increase in study and construction costs of 10% per year ➢ BHSTE staff could oversee expanded program within current work force	➢ System efficiency increases
6. Review and Update the Traffic Signal Permit Process	➢ Review committee involvement – estimated at 20 people periodically for one year ➢ Legal review	➢ Opportunity for improved management, maintenance and performance of traffic signal systems
7. Establish Operational Audits Program	➢ PennDOT staff involvement ➢ Municipal and stakeholder involvement ➢ Validation and analysis	➢ Will promote a greater maintenance effort and awareness ➢ Will provide important feedback as to system performance
8. Complete Updates and Revisions to PennDOT Traffic Signal Publications	➢ Technical review and development costs ➢ Production and distribution costs	➢ Web distribution will reduce production costs ➢ Will promote greater awareness of the policies and procedures and any changes in direction
9. Allocate a Portion of Any New Funding Increase to Signals	➢ A resource commitment from new revenues	➢ Recognition that an expanded traffic signal program will have significant systems operations benefit.

Exhibit 9.1: Recommended Resource Considerations

Solution	Resource Requirements	Resource Benefits
10. Provide Incentives for Operational Enhancements	➢ Proving incentives for enhancements ➢ Staff evaluation	
11. Encourage Regional Maintenance Contracts with Operational Incentives	➢ Providing incentives for operational enhancement	➢ May limit redundant activities by neighboring municipalities ➢ Improved maintenance procedures may reduce repair costs
12. Provide Incentives for Interjurisdictional Coordination	➢ Providing incentives	➢ Limits redundant activities

10. Recommended Action Plan

The timeframe for implementation of any potential solution is based on the ease and feasibility of implementation as well as resources needed for implementation. This section provides some initial recommendations to inform an action planning process assuming the Department advances the twelve Tier I recommendations.

Exhibit 10.1: Recommended Action Plan

Solution	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Implementation Strategy
1. Develop of an Asset Management System	Short Term	➢ An asset management tool is vital for efficient planning of other signal system programs and initiatives. For that reason, this solution should be treated as a top priority. ➢ The vision of the system would be a multi-agency tool that could be used to perform a variety of functions and querying capabilities ➢ A pilot or early action item could be to develop formal functional requirements for an asset management system, to review those requirements versus existing systems, and to develop and deploy a system for testing and phased development.
2. Pursue Tiered Operations and Maintenance on Critical Corridors	Short Term	➢ An interjurisdictional and tiered approach to traffic signals along critical corridors will provide an opportunity for developing timing plans for incident/event management coordination. Tiered operation may include municipal maintenance and some PennDOT operational responsibility. ➢ Need to define and identify "critical corridors>" ➢ Critical corridors should include the development of a Corridor Consortium that meets on a regular (but not time intensive) basis to discuss issues that relate to efficient transportation along each corridor. ➢ There are several corridors that are viable candidates for pilot programs.
3. Pursue Tiered Operations and Maintenance for most Signals	Long Term	➢ This holistic approach to signal systems would improve interjurisdictional coordination through regional and statewide signal committees. ➢ Participation in Regional Signal Committees should not be time-intensive and should include representation from Critical Corridor Consortiums. ➢ This solution will be difficult to implement. Despite nationwide success with the tiered approach, convincing municipalities to cede control of signals will be a difficult proposition. ➢ Tiered operations and maintenance on critical corridors (see previous recommendation) can be more easily piloted and tested than a similar approach on a statewide approach. The success of that program should be used as a barometer to determine if a similar approach should be attempted on a statewide level. ➢ Requires consideration of funding and human resources.

Exhibit 10.1: Recommended Action Plan

Solution	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Implementation Strategy
4. Promote a "Holistic" Approach to Signal Management	Short Term	➢ Recommendation 1 and 3 laid the foundation for a holistic approach to signal systems management. ➢ To establish a holistic approach to signal system management, several elements need to occur: • Stakeholders need a tool to assess regional traffic signal needs (asset management tool) and need to prioritize signal enhancement projects (Regional Traffic Signal Improvement Program) • Operations needs to be considered in the funding process through the involvement of ITS Coordinating Councils and Regional Signal Committees • Traffic signal enhancements and operation need to be consistent and supported by the District's Transportation System Operations Plan (TSOP). • Projects/ investments need to demonstrate quantifiable benefits ➢ Regions with well-organized planning organizations as well as those with ITS Councils may be more equipped to pilot and pursue such a solution.
5. Expand Traffic Signal Enhancement Initiative (TSEI) and Congested Corridor Improvement Program (CCIP)	Short Term	➢ Both the Traffic Signal Enhancement Initiative and the Congested Corridor Improvement Program are valuable tools in congestion reduction. ➢ Each program should be expanded at a minimum rate of 10 percent per year. ➢ Additionally, both processes should be refined, if needed, in order to make implementation of improvements as timely as possible. ➢ Program results should continue to focus on improvements such as timing plans that can be implemented without additional study.
6. Review and Update the Traffic Signal Permit Process	Short Term	➢ The review and update should be done in two phases: Technical and Legal. ➢ By addressing each phase individually, there is a better likelihood that one phase will not derail the progress on another phase. ➢ Updating the permit process requires support by Districts, local municipalities and legal counsel. ➢ One strategy might be to "phase-in" new aspects into the existing permit process. ➢ Another approach may be to separate technical aspects from legal aspects so that technical revisions can take place even if legal issues slow the revision process. ➢ Traffic signal permitting is an ongoing practice, the best approach may be to review the current process, identify technical revisions and then identify legal revisions.

Exhibit 10.1: Recommended Action Plan

Solution	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Implementation Strategy
7. Establish Operational Audits Program	Short Term	➢ Operational audits are a low-cost and effective way to identify signal system enhancements. ➢ Individual audit teams can be organized with minimal impacts to resources; however, the overall program requires consideration of human and financial resources. ➢ Ideally, critical systems should be evaluated in detail every three to five years. ➢ Guidelines and protocols for performing operational audits should be established so that key stakeholders are involved/ aware of the process and as such can promote needed improvements.
8. Complete Updates and Revisions to PennDOT Traffic Signal Publications	Short Term	➢ PennDOT is currently updating several traffic signal publications. ➢ These publications should continue to be updated. ➢ Where deficiencies in PennDOT publications exist, national publications .should be identified or additional materials should be developed ➢ Where possible, publications should be made available in electronic format and/or via a website to reduce production and mailing cost.
9. Allocate a Portion of Any New Funding Increase to Signals	Long Term	➢ TAC is recommending that a portion of any new funding source be allocated for signal systems operations and maintenance; i.e., an increase in the gasoline tax is one example. ➢ Another solution is a one-time bond financing of traffic signal projects. This would have the benefit of allowing a major initiative for signal improvement fast tracking but should be tied to some specific revenue stream to secure the debt service and to ensure continuing maintenance and operational funding. ➢ The Commonwealth should also consider a legislative change that would automatically index fuel taxes and license/ registration fees to a standard inflation rate, such as the consumer price index. ➢ Dedicate excess revenues from any future automated red-light enforcement (ARLE) program to signal improvements.
10. Provide Incentives for Operational Enhancements	Long Term	➢ The incentive should cover a percentage of the evaluation, design and implementation of the enhancement provided these benefits can be documented. ➢ The exact percentage of incentive should be further evaluated to determine an appropriate level that encourage municipal participation, but does not result in unlimited requests. ➢ This initiative is contingent on the acquisition of additional funding for signal systems operations, maintenance, and enhancement.
11. Encourage Regional Maintenance Contracts with Operational Incentives	Short Term	➢ As part of the update to PennDOT Publication 191, *Guidelines for the Maintenance of Traffic Signal Systems (recommendation 8),* the existing standard shared maintenance and regional maintenance contracts should be updated to be used by municipalities and regional consortiums. ➢ Since shared maintenance (without incentives) could be implemented in the current climate, this initiative is highly feasible and would be more widely supported if guidance and operational incentives were provided from a new funding source. ➢ The update to Publication 191 and new funding allocations should be considered when pursuing this initiative.

Exhibit 10.1: Recommended Action Plan

Solution	Implementation Timeframe (Short Term – < 2 years) (Long Term – > 2 years)	Implementation Strategy
12. Provide Incentives for Interjurisdictional Coordination	Long Term	➢ This recommendation is one that should be reasonable and balanced to leverage resources, but at the same time does not result in an oppressive degree of "strings attached." ➢ Incentive programs will need to meet the needs of both the Department as well as the recipient. ➢ If a new funding source were dedicated to signal systems, such incentives would be more easily provided.

11. Conclusions

The State Transportation Advisory Committee recognizes the effective and efficient movement of people and goods will require new investments, additional capacity, expanded infrastructure and improved operations of existing transportation facilities.

Improved transportation operations represent one especially important strategy given the relatively low costs compared to the high benefits of operations increasing system capacity. While each strategy is important and has its rightful place, efforts to improve operations cannot be missed in this fiscally constrained environment.

This study fosters a comprehensive approach to assessing traffic signal improvement needs statewide and advancing a strategy that addresses those needs in some priority fashion. Improved traffic signal systems will help ease congestion, will enhance safety, and have indirect benefits such as improved air quality.

Study Objectives

- Produce an evaluation of relevant issues associated with the policies and practices of traffic signal systems throughout the Commonwealth.
- Identify alternatives to reduce congestion.
- Make feasible recommendations for ways traffic signal systems might be better planned, deployed, and managed to improve safety and congestion management.

Pennsylvania signal systems are a $1 billion asset that are not managed and operated to their fullest. That is important context for evaluating the issues associated with the policies and practices of traffic signal systems. Key themes identified within this study include:

- Signal systems are an asset that should be better managed as such so that systems can be better planned, maintained and operated to reduce congestion
- Signal systems need be both maintained and operated. Operations include the development of appropriate operations parameters/standards, addressing special needs such as events, homeland security and incidents, and providing oversight to ensure systems are functioning properly and efficiently.
- Signal systems should be a shared responsibility that requires the multi-jurisdictional cooperation and input of local municipalities, PennDOT, planning organizations and other stakeholders.
- Signal systems cannot only be considered on a microscopic, jurisdictional level, but should also be considered on a corridor and regional level.
- A number of policy and procedures such as signal permitting need to be evaluated to address appropriate roles and responsibilities; the importance of signal systems and the highway occupancy permit process with regard to signal systems.

- Technology is rapidly changing, requiring continual training and education to ensure that signal systems can be designed, maintained and operated efficiently.
- Procurement policies can discourage technology implementation. Creative approaches are needed to both encourage continued research, and more importantly, to test and disseminate that research in an applied way throughout the Commonwealth.
- Funding for improved traffic signal systems should be considered as a part of any future state transportation funding increases. This will serve to emphasize the importance of efficient operations. New funding can also leverage many other favorable results, including a performance-based approach for receiving funds based on updated standards.

  Although much can be accomplished without increase funding, a new funding source would allow recommendations to be implemented more quickly and to a far greater level as well as provide additional support for operations and maintenance.

By improving the coordination and performance of our traffic signal systems through better maintenance, operations and management practices, the following benefits can be realized:

- Reduced congestion on many of our major arterials
- Optimize the capacity of our existing infrastructure
- Improved air quality and decreased fuel consumption
- Reduced congestion-related crashes
- Improved response of emergency vehicles/services
- Promote more efficient transit system(i.e., transit signal preemption which allows transit vehicles to control signals)
- Respond to non-recurring special needs such as incident management, homeland security and special events
- Improved regional cooperation on signal system management and related transportation issues
- Improved utilization of existing and future resources by better planning, deploying and managing signal systems
- Stimulate economic development by making our roadways and our cities more accessible.

APPENDIX A

July 1ST Traffic Signal Systems Workshop Attendance Sheet

ATTENDEE LIST / SIGN-IN SHEET
Thursday, July 01, 2004
State Transportation Advisory Committee - Congestion Mgmt. Task Force
Gannett Fleming Offices - Camp Hill, PA

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APPENDIX B

Survey and District Feedback

APPENDIX C

Master Issues List

Master Issues List

Source	#	Issue	Category
WORKSHOP	1	Ownership	Policy & Planning
WORKSHOP	2	Regional priority of signals from MPO/RPO's needs to be considered	Policy & Planning
WORKSHOP	3	To require buttons and signage where there is no crosswalk is a waste of sources	Policy & Planning
WORKSHOP	4	Signal spacing policies are needed	Policy & Planning
WORKSHOP	5	Access management and land use policies are needed	Policy & Planning
WORKSHOP	6	Operational control and monitoring - Who should do it?	Policy & Planning
WORKSHOP	7	Emergency preemption policy is needed	Policy & Planning
WORKSHOP	8	Overall interaction regarding signal control needs to be identified	Policy & Planning
WORKSHOP	9	Signals are seen as an unfunded local mandate	Policy & Planning
WORKSHOP	10	Administrative code as it relates to procurement	Policy & Planning
WORKSHOP	11	No research or demonstration programs	Policy & Planning
WORKSHOP	12	Limited ITS policy at state level	Policy & Planning
WORKSHOP	13	Need to address strategic corridors	Policy & Planning
WORKSHOP	14	Policy doesn't allow the use of systems	Policy & Planning
SURVEY	A1	Need to streamline the signal modification process between the municipality and PennDOT	Policy & Planning
SURVEY	A3	Should PennDOT own and maintain all signals or at least those on state roads?	Policy & Planning
OTHER	A4	Should PennDOT control the operations of key system and have municipalities maintain?	Policy & Planning
OTHER	A5	We do not have an effective and comprehensive traffic signal "program." Rather, it seems we directly or indirectly use our lack of ownership as a reason to not aggressively address traffic signal related issues. Before a comprehensive traffic signal program can be developed, we need to gain a better understanding of the existing asset. The information needed would include signal locations, types of equipment, year of installation, etc. Once this information has been captured, goals and objectives can be established along with the ways of achieving them.	Policy & Planning
OTHER	A6	Develop program to analyze corridors, but include detailed timing adjustments - similar to congested corridors	Policy & Planning
OTHER	A7	No policy for reassessing timing plans	Policy & Planning
OTHER	A8	Signal ownership and maintenance is not wanted by some (usually smaller) agencies	Policy & Planning
WORKSHOP	15	Needs a dedicated funding source (like ECONS experience) on the state level	Funding
WORKSHOP	16	Operations needs funding too	Funding
WORKSHOP	17	Benefit/cost ratios as funding consideration	Funding
WORKSHOP	18	Need separation in funding between signal systems and new equipment (e.g safety project)	Funding

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WORKSHOP	19	Existing policy of requiring financial commitment for a traffic signal study because don't know if a signal is needed	Funding
WORKSHOP	20	Funding for data collection is often too little	Funding
WORKSHOP	21	Must look at signals that have been installed to make sure they are still functioning properly	Funding
WORKSHOP	22	Developers don't always get paid to look at whole system	Funding
WORKSHOP	23	Liquid fuels allocation outdated (doesn't consider signals & adding a portion for signals)	Funding
WORKSHOP	24	Tolls?	Funding
SURVEY	A9	Need dedicated funding to operate and maintain signal systems	Funding
SURVEY	A10	Funding should come from Liquid Fuels	Funding
OTHER	A11	Liquid Fuels program is mileage based and does not consider number of signals (or other technology) in estimating???	Funding
OTHER	A12	Timing plans often not updated (or not updated with current traffic) due to the cost of data collection	Funding
OTHER	A13	Although ownership is often an issue that arises when discussing traffic signals, funding typically seems to be one of the real factors behind the concerns. It appears that the formula (liquid fuels formula) provides no weight for traffic signal ownership. We feel that it would be very beneficial to reevaluate the formula to address the ownership and maintenance of traffic signals.	Funding
OTHER	A14	During the discussion, it was brought up that municipal ownership of traffic signals on state roads is an unfunded mandate. In essence, municipalities feel they are maintaining technology that benefits the Department. It would be easy to argue both sides, but in reality, the traffic signals benefit everyone. One of the potential solutions identified was a dedicated funding source at the state level to help fund traffic signals. We feel that the Traffic Signal Enhancement Initiative (TSEI) has begun a movement in this direction. Our hope is to continually grow and expand the TSEI program so we will be able to make significant improvements to traffic signals on state highways. However, TSEI is not a comprehensive program, and is only a very small representation of what is needed.	Funding
OTHER	A15	We need a holistic approach to funding. This means we need to evaluate all of the areas where funding is needed and devise responsible parties, ways to address, etc. This would include installation, modernization, safety, retiming, maintenance, operation, training, etc.	Funding
WORKSHOP	25	Holistic approach to corridors, not municipality only, there are a few consortiums around the state	Jurisdictional & Ownership
WORKSHOP	26	Integration of signal technology is needed	Jurisdictional & Ownership
WORKSHOP	27	Some municipal official don't know that they own signals	Jurisdictional & Ownership
WORKSHOP	28	Coordination by system type across jurisdictions is needed	Jurisdictional & Ownership
WORKSHOP	29	Coordination with utilities (space on line for fiber optics for interconnection)	Jurisdictional & Ownership
WORKSHOP	30	Municipal personal relationships are sometimes dysfunctional	Jurisdictional & Ownership
WORKSHOP	31	Municipal boundary in center of intersection (who owns the signal?)	Jurisdictional & Ownership

Master Issues List

WORKSHOP	32	Tiered approach in New Jersey (State, County, Municipal ownership) cross jurisdictional corridors sometimes works	Jurisdictional & Ownership
WORKSHOP	33	Non uniformity among locals. Inconsistencies with municipalities	Jurisdictional & Ownership
WORKSHOP	34	The amount of State Roads in PA too great to manage all the signals (lack of county and regional ownership)	Jurisdictional & Ownership
WORKSHOP	35	Vendor geographic restrictions in the state prohibit municipalities from dealing with who they want	Jurisdictional & Ownership
SURVEY	A16	Need to address signal systems across municipal boundaries or even at a regional level	Jurisdictional & Ownership
OTHER	A17	Disconnect on many corridors when Interjurisdictional boundaries are crossed due to varying timing patterns and technologies. Lack of single entity in control.	Jurisdictional & Ownership
OTHER	A18	One of the toughest challenges when it comes to traffic signal operations is coordination of systems across municipal boundaries. These issues can begin in the early stages of a project when funding responsibilities for installation are determined, and continue after the project is complete when maintenance and operation responsibilities surface. Solutions to these issues could vary from jurisdiction to jurisdiction and may involve ideas such as oversight from organizations like the County or MPO/RPO, or possibly the creation of municipal consortiums focused on transportation issues. Ensuring that critical transportation corridors function to the best of their ability should be a concern of PennDOT. This is also consistent with the new Mobility Strategic Focus Area Executive Goal to “effectively and efficiently operate the transportation system.” As such, we need to facilitate better communications between the respective organizations and work with them to determine solutions that promote traffic signal coordination.	Jurisdictional & Ownership
OTHER	A19	Better coordination of traffic signals along critical corridors will provide an opportunity for developing timing plans for incident/event management coordination. With systems properly operating, timings can be added to controllers for situations involving heavy traffic or detours for incidents occurring on adjacent routes. This type of coordination is currently lacking throughout the state and could greatly improve traffic flow during critical times.	Jurisdictional & Ownership
WORKSHOP	36	PennDOT is lacking authority to fix signals or authority is not enforced	Enforcement
WORKSHOP	37	Red light running is an issue	Enforcement
WORKSHOP	38	Yellow and red times too long according to some	Enforcement
WORKSHOP	39	Automated enforcement is not allowed in PA, except for pilot project	Enforcement
WORKSHOP	40	Maintenance contracts bid in a way that they cannot be enforced properly because of deteriorated conditions	Enforcement
WORKSHOP	41	191 guidelines need to be updated because they are outdated	Enforcement
WORKSHOP	42	Asset management criteria (via 191, etc.) but there is no teeth or incentives	Enforcement
WORKSHOP	43	Operational audits reporting would make municipalities aware of problems	Enforcement
WORKSHOP	44	Difficult to enforce maintenance issues because of low funding (liquid fuels constraint)	Enforcement
WORKSHOP	45	Standard scopes of work for signal related projects like retiming or maintenance	Procurement
WORKSHOP	46	State contracts (no bid) are needed for tech procurement	Procurement
WORKSHOP	47	Economies of scale (preparing bid, relationships with vendors)	Procurement

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WORKSHOP	48	Competitive bids don't always work. Low bid versus performance	Procurement
WORKSHOP	49	Standardization of equipment needs explored	Procurement
WORKSHOP	50	Standardizing hardware and software systems	Procurement
WORKSHOP	51	Municipalities get in over their head with some vendors of hardware and software systems	Procurement
WORKSHOP	52	Compatibility promises not enforced in practice	Procurement
WORKSHOP	53	Market diversity needs to be balanced with standardization	Procurement
WORKSHOP	54	Maryland state owned equipment, but municipalities are pushed to use the same signals	Procurement
WORKSHOP	55	Is there a problem with Low Bid? Should it be done by merit and qualifications	Procurement
WORKSHOP	56	Asking municipalities without technical staff to procure best equipment and services	Procurement
WORKSHOP	57	State contracts are not currently considered because PennDOT doesn't buy signals. Would be new ground	Procurement
OTHER	A18	No stockpile of poles and controllers results in operational impacts when a signal is damaged	Procurement
OTHER	A19	Current sole source requirements do not entirely alleviate technology conflicts	Procurement
WORKSHOP	58	Testing system done for materials and equipment used by municipalities not PennDOT	Technology
WORKSHOP	59	PennDOT cannot test new technology because the municipality has to pay for it if it doesn't work	Technology
WORKSHOP	60	State doesn't have testing facility must rely on independent traffic signal testing	Technology
WORKSHOP	61	LTAP testing program is a resource	Technology
WORKSHOP	62	Municipalities can't try certain elements because of PennDOT standards	Technology
WORKSHOP	63	Can work out deal with organizations that already exist	Technology
WORKSHOP	64	Need to embrace technology	Technology
WORKSHOP	65	How to train personnel to handle the technology	Technology
WORKSHOP	66	Hard to keep people proficient in signals because a constant retraining	Technology
WORKSHOP	67	Separation of operations	Technology
WORKSHOP	68	Very difficult to keep up with technology, operations, policies, permits, procurements	Technology
WORKSHOP	69	Technology isn't always utilized for funding reasons	Technology
WORKSHOP	70	Need individuals certified by the state, standards for groups to understand systems and work	Technology
WORKSHOP	71	Municipalities may not be willing or may not have the funding to hire the right people	Technology
WORKSHOP	72	Money wasted on overly complex systems when they aren't needed, limiting the number of project that can be done because of budget	Technology
WORKSHOP	73	No standard spec provisions	Technology
WORKSHOP	74	There is no licensing for traffic signal maintenance	Technology

Master Issues List

WORKSHOP	75	No demonstration project funding	Technology
WORKSHOP	76	Municipalities maintaining technology that benefits Penn Dot (emergency detour routes)	Technology
SURVEY	A20	Need to improve the process of accepting new technologies	Technology
OTHER	A21	Delay in creating standard items for new technology resulting in a variety of special provisions. Testing policy?	Technology
OTHER	A22	Adaptive signal systems will be flexible and monitorable, but many municipalities will not be able to support that level of technology	Technology
WORKSHOP	77	Need time to monitor systems to make sure they are accurate. Need to follow up, often outside the scope of the construction	Engr and Construction
WORKSHOP	78	No mechanism to see whether HOP is followed. Municipalities can put a requirement, but there are difficulties with enforcement	Engr and Construction
WORKSHOP	79	408 specs are hard to keep up to date	Engr and Construction
WORKSHOP	80	Limited construction inspection for signals	Engr and Construction
WORKSHOP	81	Permit inspectors for HOP don't have signal background. State doesn't inspect signal on non-state roads	Engr and Construction
WORKSHOP	82	Certification for people who will be constructing and maintaining signals	Engr and Construction
WORKSHOP	83	Engineer can work with municipality to show how to use the machine, fine tuning systems	Engr and Construction
WORKSHOP	84	Engineer system to take its own counts if designed properly	Engr and Construction
WORKSHOP	85	Some of the worst congestion on Saturdays, need to do more weekend counts.	Engr and Construction
WORKSHOP	86	Timing plan considers too few times not incidents or weekends	Engr and Construction
WORKSHOP	87	Issuing traffic signal permits or modifications takes a long time. Need flexibility, especially in timings.	Engr and Construction
WORKSHOP	88	Comprehensive review of the process	Engr and Construction
WORKSHOP	89	General disconnect between engineering and construction side of things	Engr and Construction
WORKSHOP	90	Discipline fragmentation. More joint effort needed.	Engr and Construction
SURVEY	A23	Need flexible standards (foundations and utilities) so that field issues can be addressed	Engr and Construction
SURVEY	A24	Need to develop common specifications	Engr and Construction
OTHER	A25	Current TC standards do not support today's loading requirements	Engr and Construction
OTHER	A26	Limited deployment of adaptive and real-time systems	Engr and Construction
OTHER	A27	Traffic associated with a development may only include part of a system and may not consider adjusting the system cycle lengths	Engr and Construction
OTHER	A28	Signal permit and construction drawings vary by District	Engr and Construction
WORKSHOP	91	Homeland security and incident management response should be considered when evaluating systems	Operations & Management/Efficiency
WORKSHOP	92	Manpower for dedicated workforce with improvements	Operations & Management/Efficiency
WORKSHOP	93	Broader plan (between jurisdictions, ITS, etc.) needed for signals	Operations & Management/Efficiency
WORKSHOP	94	New partners (911 center in Montgomery County) need to be explored	Operations & Management/Efficiency

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WORKSHOP	95	We do not operate signals for the most part. They are constructed. Not a holistic view	Operations & Management/Efficiency
WORKSHOP	96	The highways aren't being operated just built and maintained	Operations & Management/Efficiency
WORKSHOP	97	Need operations money, separate from other issues	Operations & Management/Efficiency
WORKSHOP	98	Signals can't compete with maintenance issues for money	Operations & Management/Efficiency
WORKSHOP	99	FHWA is trying to get away from funding categories	Operations & Management/Efficiency
WORKSHOP	100	Someone still needs to prioritize, even if it is on the state level	Operations & Management/Efficiency
WORKSHOP	101	Operations and safety need to go hand in hand	Operations & Management/Efficiency
WORKSHOP	102	Highway management is a consideration	Operations & Management/Efficiency
WORKSHOP	103	Traffic management centers (will they exist in the future?) need to include signal systems	Operations & Management/Efficiency
WORKSHOP	104	Will we manage traffic in the future	Operations & Management/Efficiency
WORKSHOP	105	MPO/RPO separating out money may not work, public may need to be involved	Operations & Management/Efficiency
WORKSHOP	106	MPO/RPO funding is a dynamic issue people do listen to needs, professional staff needs to make voting members of MPO/RPO	Operations & Management/Efficiency
SURVEY	A29	Need an asset management tool to track maintenance and operations.	Operations & Management/Efficiency
SURVEY	A30	Need to better utilize closed-loop systems	Operations & Management/Efficiency
SURVEY	A31	Should PennDOT maintain and operate signals?	Operations & Management/Efficiency
SURVEY	A32	Should we define typical operational parameters for type of systems?	Operations & Management/Efficiency
SURVEY	A33	Should there be criteria developed for traffic responsive systems?	Operations & Management/Efficiency
OTHER	A34	Municipal timing updates require a permit request change and modification of permit which is very bureaucratic and promotes changing w/o notifying PennDOT.	Operations & Management/Efficiency
OTHER	A35	Pedestrian crosswalk times often ignored when developing coordinated timing plans resulting in out-of-sync timings when ped phase is actuated	Operations & Management/Efficiency
OTHER	A36	No guidance on selection of offset point (start of yellow or start of green) which will early return progression	Operations & Management/Efficiency
OTHER	A37	Closed loop computer and software systems often out of date	Operations & Management/Efficiency
OTHER	A38	For event corridors, primary access may be manual controlled but no adjustment is made to other intersections	Operations & Management/Efficiency
OTHER	A39	Incentive for well maintained and operationally up-to-date. Maintenance doesn't mean it is operationally up to date	Operations & Management/Efficiency

Master Issues List

OTHER	A40	Some routes as detours for major routes need adjustment to timings when used	Operations & Management/Efficiency
OTHER	A41	The maintenance and operation of traffic signals have always been an issue in Pennsylvania. Much of the signal equipment on our roads is outdated and in need of replacement. In some cases, the old traffic signal equipment is not capable of performing the operations needed to handle the existing traffic conditions. Even in cases with modern equipment, timings are often installed and never updated to address the ever increasing traffic volumes. PennDOT and the local municipalities need to evaluate ways to better operate and maintain traffic signals to ensure that they function at their highest capability.	Operations & Management/Efficiency
WORKSHOP	107	Municipalities can't afford maintenance	Maintenance
WORKSHOP	108	191 guidelines need to be updated because they are outdated	Maintenance
WORKSHOP	109	Local state ping pong of payment	Maintenance
WORKSHOP	110	Signals aren't a funding priority	Maintenance
WORKSHOP	111	Some municipalities don't even know when the detector is broken	Maintenance
WORKSHOP	112	Operational maintenance isn't optimum	Maintenance
WORKSHOP	113	Funding though RPO's & MPO/RPO's should be considered	Maintenance
WORKSHOP	114	Cooperative agreements for maintenance may be a solution	Maintenance
WORKSHOP	115	Enforcement of maintenance issues needed	Maintenance
OTHER	A42	Pooled maintenance programs may be beneficial to neighboring municipalities with limited signal equipment to ensure timely response and consistency of equipment	Maintenance
WORKSHOP	116	Red light running needs to be a focus	Safety
WORKSHOP	117	Liability, funding, and proper maintenance can lead to unsafe signals	Safety
WORKSHOP	118	Operational related issues related to rear ends	Safety
WORKSHOP	119	Walk don't walk bulbs neglected	Safety
WORKSHOP	120	Every 6 months period not often enough to keep a signal operating safely (191 protocol)	Safety
WORKSHOP	121	Signal is unlike bridges or signs where there are no inspections. No state mandated inspection period.	Safety
WORKSHOP	122	Protected phasing not implemented	Safety
WORKSHOP	123	No meaningful rollup unlike bridges	Safety
WORKSHOP	124	Even if regular inspection there is still a funding shortage to fix this	Safety
WORKSHOP	125	Bridges have a federal mandate	Safety
WORKSHOP	126	Traffic signal failure is not viewed as being as dangerous	Safety
WORKSHOP	127	Older signals do not have adequate number of signal heads, safety issue with outdated systems	Safety
WORKSHOP	128	All red clearances not always correct	Safety
SURVEY	A43	Need to integrate more preemption systems	Safety
OTHER	A44	No specific guidance on deployment of preemption systems	Safety

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OTHER	A45	Lack of ability to override systems in time of emergency/ homeland security incidents	Safety
WORKSHOP	129	Equipment knowledge gaps	Training and Expertise
WORKSHOP	130	IMSA training good but not accessible	Training and Expertise
WORKSHOP	131	Training needed in design	Training and Expertise
WORKSHOP	132	Training needed in construction	Training and Expertise
WORKSHOP	133	Training needed for consultants	Training and Expertise
WORKSHOP	134	Electrical and IT issues not covered by Civil Engineers who work in transpiration	Training and Expertise
WORKSHOP	135	Joint training courses needed	Training and Expertise
WORKSHOP	136	Traffic career track may not be best for overall career	Training and Expertise
SURVEY	A46	Need programs to educate municipalities about signal systems	Training and Expertise
OTHER	A47	PennDOT retirement practices has created expertise vacuum	Training and Expertise
OTHER	A48	Publication 149 has not been updated in many years	Training and Expertise
OTHER	A49	Poor/ uneducated development of timings	Training and Expertise
OTHER	A50	With the exodus of experienced personnel and the influx of new employees to the traffic signal area, training has become a critical factor. A comprehensive approach to training is needed to develop a highly knowledgeable staff in this rapidly changing field of technology. The need for training, however, extends beyond PennDOT to include consulting, municipal personnel, and others involved in the planning and design of traffic signal systems, the installation of the equipment, and proper operation and maintenance. Training also needs to bridge the gap between civil engineering, IT, electrical, and other disciplines involved with traffic signal systems.	Training and Expertise
WORKSHOP	137	Residents don't know who to talk to about signals	Public Education
WORKSHOP	138	Vendors aren't utilized enough as a source of information	Public Education
WORKSHOP	139	Lack of knowledge of what the equipment is capable of doing among those implementing it	Public Education
WORKSHOP	140	Need to explain to public the benefit of signals	Public Education
WORKSHOP	141	Public is the eyes on street, but cannot diagnose problems	Public Education
SURVEY	A51	Need to methods to inform public about signals and new technologies other than adding signs.	Public Education
SURVEY	A52	If PennDOT owned signals then citizen issues can be more directly addressed.	Public Education
OTHER	A53	Public are not aware of signal elements (loops) and therefore cannot communicate problems	Public Education
WORKSHOP	142	Municipalities who can't afford a signal want to avoid a study to avoid liability	Legal/Liability
WORKSHOP	143	Municipalities don't know liability until they are sued	Legal/Liability
WORKSHOP	144	If it is not operating according to permit the municipality is liable	Legal/Liability
WORKSHOP	145	it doesn't matter if the accident was related to timing	Legal/Liability
WORKSHOP	146	Warrants for signals called for by developers and not installed - what are the legal issues related to that	Legal/Liability
WORKSHOP	147	Traffic impact study, hesitancy to know about issue if there isn't funding to fix it	Legal/Liability

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WORKSHOP	148	Municipalities don't have leverage, even with impact	Legal/Liability
WORKSHOP	149	Asset management strategy mange risk	Legal/Liability
WORKSHOP	150	Highway occupancy permit enforcement leads to signal problems.	Legislative
WORKSHOP	151	Red light running camera enforcement only cities of first class	Legislative
WORKSHOP	152	Citation mailing is an issue with red light enforcement	Legislative
WORKSHOP	153	New Jersey utilities funds $30 per 8 inch bulb… no grants in PA because not required. The legislation is not in effect.	Legislative

APPENDIX D

Reviewed Resources

Pennsylvania Resources and Studies

Resource	Summary
Southwestern Pennsylvania Regional Planning Commission. Survey of Municipal Traffic Practices. March 1996. ***Key Resource***	The Southwestern Pennsylvania Commission (SPC), the Metropolitan Planning Organization for the 10-county Pittsburgh region, conducted a traffic signal survey in 1996. This report captured data from 81 municipalities concerning ownership, staffing, maintenance, signal types, inspection, capital programming, funding, and needed improvements. The Survey served as the foundation for SPC's *Traffic Signal Opportunities for Southwestern Pennsylvania*.
Southwestern Pennsylvania Regional Planning Commission. Traffic Signal Opportunities for Southwestern Pennsylvania. June 1996. ***Key Resource***	In this report, SPC assessed the needs and location of traffic signals and recommended policy and procedural changes to improve traffic signal systems. SPC recommended increased funding, PennDOT responsibility for signals located on state roadways, promotion of traffic signal projects as a PennDOT District priority, and PennDOT responsibility for signal improvements.
Legislative Budget and Finance Committee. A Joint Committee of the Pennsylvania General Assembly. A Review of Traffic Congestion Trends and Related Mitigation Efforts. September 2001 ***Key Resource***	Primarily focused upon congestion mitigation, this report provides data regarding signal improvements and signal funding. Additionally, the report explains the relationships between traffic signals and access management, Highway Occupancy Permits (HOP's), and the Municipalities Planning Code (MPC).
Barber, P.E., Steven. Traffic Signal Warrants. Pennsylvania State University. The Pennsylvania Local Roads Program. June 1997	This technical information sheet describes various warrants that should be satisfied prior to installing a traffic signal.
Insurance Institute for Highway Safety. Statement Before the Pennsylvania House of Representatives Transportation Committee. Red Light Violations and Red Light Cameras. November 7, 2001.	This document provides an overview of red light running data and red light camera best practices in support of authorizing the use of red light cameras in Pennsylvania.
National Association of Development Organizations. Regional Transportation Online Center. Pennsylvania: The Rural Context for Transportation Consultations. www.nado.org/rtoc/library/pa.html.	This online article provides background demographic and governmental data on Pennsylvania with a focus on rural transportation issues.
Pennsylvania Department of Community and Economic Development. Governor's Center for Local Government Services. Subdivision and Land Development in Pennsylvania - Planning Series #8. March 1999	This resource contains information about subdivision and land development controls in Pennsylvania. It contains an overview regarding transportation improvements, impact fees, and off site improvements.
Pennsylvania Department of Transportation. County Liquid Fuels Tax and The Liquid Fuels Tax Act 655. January 1987.	This publication explains the procedures, regulations, and services of PennDOT as they relate to the administration of the Liquid Fuels Tax Act which authorizes the allocation of these funds to Pennsylvania's municipalities.
Pennsylvania Department of Transportation. PennDOT Master Policy Manual. January 1983.	This Department-wide policy applies to the study, installation, and maintenance of traffic signals on all highways in the Commonwealth.
Pennsylvania Department of Transportation. PennPlan Moves! Pennsylvania Statewide Long Range Transportation Plan: 2000-2025. January 2000.	This plan reflects the long range transportation needs and desires of the residents of the Commonwealth. It provides statewide goals, objectives, and performance measures including Intelligent Transportation Systems (ITS) and congestion management.
Pennsylvania Department of Transportation. Pennsylvania Guidelines for the Maintenance of Traffic Signal Systems (Pub. 191), 1989.	This document provides general guidelines to the responsible parties for the maintenance of traffic signals.
Pennsylvania Department of Transportation. Pennsylvania Traffic Signal Design Handbook (Pub. 149), 1988.	This establishes guidelines for the design and operation of traffic control signals on all streets and highways in Pennsylvania. It is to be used by PennDOT, county and municipal personnel, consulting engineers or others involved in the design or operation of traffic control signals.

Resource	Summary
Pennsylvania Department of Transportation. Pennsylvania's Highway Congestion Management Strategic Plan Stakeholder Conference Results. August 1999.	This compendium of the October 1998 Congestion Management Stakeholder Conference sets forth Pennsylvania's goals with regard to congestion issues. This document provides the mission and goals for the completed Congestion Management Strategic Plan and calls for traffic signal upgrades and timing enhancements.
Pennsylvania State University. The Pennsylvania Local Roads Program. Moving Forward Newsletter. "LED Traffic Signals." Winter 1998.	This article reports on the state of light emitting diodes (LED) traffic signal technology and costs, specifically within the City of Philadelphia.
Pennsylvania State University. The Pennsylvania Local Roads Program. Moving Forward Newsletter. "Traffic Signal Maintenance: Essential to a Safe and Efficient Transportation Network." Fall 1998.	This article describes the importance of traffic signal maintenance and provides a maintenance question checklist and contacts.
Pennsylvania State University. The Pennsylvania Transportation Institute. Center for Traffic Operational Analysis. Advanced Traffic Control Equipment. No date.	This report assessed current and emerging technologies in traffic signal control equipment and provided qualitative guidelines for their application.
Pennsylvania State University. The Pennsylvania Transportation Institute. Center for Traffic Operational Analysis. Congestion Management Statewide Strategic Plan. No date.	The plan provides an overview of PennDOT's congestion management-related capabilities based upon a statewide workshop and survey of current national congestion management practices.
Thomas, Lillian. "City's traffic expert laid off." Pittsburgh Post-Gazette. January 27, 2004.	This article describes the lay off of Pittsburgh's traffic engineer due to the City's budget crisis.

Handbooks and Guidelines

Resource	Summary
Traffic Control Devices Handbook 2001, ITE, 2001.	This book provides a basic overview of traffic signal operations.
Traffic Control System Operations: Installation, Management and Maintenance, ITE, 2000.	This book provides detailed guidelines for maintenance and operations.
Innovative Traffic Control Equipment Procurement Methods, ITE, 2000.	This document provides a survey of best practices in traffic control device procurement.
Operations and Maintenance of Electronic Traffic Control Systems, ITE/FHWA, 1995.	This document provides basic electronic control data based on surveys, focus groups and a literature review.
Traffic Signal Control Systems Maintenance Management Practices, TRB, 1997 Economic Implications of Congestion, TRB, 2001.	This document focuses on general maintenance. It also provides an overview based upon a literature review and survey.
ITE. A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility. 1997. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/5dz01!.pdf.	This document is a broad survey of tools for alleviating traffic congestion. Elements of this document contain information about traffic signals, though the scope of the document is far broader. There are chapters devoted to getting the most out of the existing system, increasing capacity, public transportation, managing demand, ITS, and funding.
FHWA. The Manual of Uniform Traffic Control Devices. 2003. http://mutcd.fhwa.dot.gov.	This manual sets the standard for traffic control devices in most states, including Pennsylvania.
FHWA. Communications Handbook for Traffic Control Systems. April 1993. http://ntl.bts.gov/data/9nv01!.pdf.	This handbook was written to enable transportation engineers to plan, select, design, implement, operate maintain communication systems for traffic control.
FHWA. Building the ITI: Putting the National ITS Architecture into Action. April 1996. http://plan2op.fhwa.dot.gov/pdfs/Pdf1/Edl00415.pdf.	Handbook on how to implement the National ITS Architecture.

Articles and Web Resources

Resource	Summary
FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html. ***Key Resource***	This study focuses on 5 case study inter-municipal agreements related to traffic signals, with some detail into technical aspects of the signals themselves. The five case studies presented in this report demonstrate that cross-jurisdictional signal coordination is an achievable goal for any size community regardless of the number of jurisdictions involved, the type of hardware and equipment, or even the philosophical differences in timing approaches. While some agencies enter into formal agreements for maintenance of another agency's signals, informal agreements are more common for coordinating the traffic signal at a common border.
GAO. Transportation Infrastructure: Benefits of Traffic Control Signal Systems Are Not Being Fully Realized. March, 1994. http://www.its.dot.gov/JPODOCS/REPTS_PR/4R701!.PDF. ***Key Resource***	This study reviews (1) the benefits of traffic control signal systems; (2) the problems that state and local agencies face in implementing, operating, and maintaining effective signal systems; (3) the relationship of the current signal systems to emerging technologies like Intelligent Vehicle/Highway Systems; and (4) the role of the Federal Highway Administration in assisting state and local governments with their signal systems through reviews of plans and other means. The recommendations focus on changes that can be made at the FHWA to improve the utilization of this technology.
Pearson, Rebecca. Traffic Signal Control Website. Hosted by the Institute of Transportation Studies at the University of California at Berkeley and Caltrans. November, 2001. http://www.calccit.org/itsdecision/serv_and_tech/Traffic_signal_control/trafficsig_report.html. ***Key Resource***	This web article is extensive description of current traffic signal systems with some useful cost and benefit information.
Hicks, Brandy, and Mark Carter. What have we learned about Intelligent Transportation Systems? Chapter 3: What have we learned about ITS? Arterial Management. December 2000. http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE/@9Z01!.PDF	This paper presents what has been learned in four principal areas of arterial management: (1) adaptive control strategies; (2) advanced traveler information systems; (3) automated enforcement; and (4) integration. The levels of deployment, benefits, deployment challenges, and future steps are presented for each category.
FHWA. Arterial Systems Management and Operations website. http://www.ops.fhwa.dot.gov/Travel/Arterials_and_Signals/Arterials_and_Signals.htm	This website is reached through the FHWA Office of Operations. It contains recent events related to arterial management and operations as well as useful links.
Transportation Management and Engineering Magazine. http://www.tmemag.com.	The website of Transportation Management and Engineering magazine contains many useful articles related to traffic signal topics.
Tarnoff, Philip J. Transportation Management and Engineering Magazine, "Can't We Raise the Bar Just a Little?" June, 2003. http://www.tmemag.com	This article highlights myths related to traffic signal costs and spending.
FHWA. Congestion and Traffic website. http://www.fhwa.dot.gov/congestion/index.htm	This website shows problems and costs of congestion. Traffic signal improvements are included as one of many strategies for improvement.

Resource	Summary
Sunkari, Srinivasa P.E. ITE Journal, "The Benefits of Retiming Traffic Signals." April, 2004.	This article is a general survey of traffic signal retiming, including information related to the constraints and savings of retiming traffic signals. There is also a list of examples of successful retiming projects and what the resulting savings were. Emphasis is given to the benefits of improving traffic signal timing including some statistics.
ITE. 21st century operations using 21st century technologies. www.ite.org/management/ppoint/ITE21stCentury.ppt.	This slideshow focuses on operations and technology improvements that will allow for 21st century congestion improvements.
Associated Press. Results of AP poll on traffic and highways. July 1, 2004.	This poll shows public views on congestion and spending issues, based on telephone interviews with 1000 adults from the 48 contiguous states. Some interesting results include that 55% of people say that traffic in their area has gotten worse in the past five years, 51% percent say that expanding public transportation should be a higher priority for public spending , and 56% would be willing to pay more in taxes if the money were used to make significant improvements in the roads and public transportation in their area.
Trafficware. In the Node, "What will you do with your free time?" Summer, 2004.	This article cites a number of resources related to hours of staff time with traffic signal systems.
FHWA. Successful Traffic Signal System Procurement Techniques. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13611.html.	This document summarizes procurement techniques for new signal technologies. It includes information on how to get the most appropriate technology for the dollar and how cities can avoid getting in over their head.
FHWA. Developing Traffic Signal Control Systems Using the National ITS Architecture. February, 1998. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/2br01!.pdf.	This document works as a how to guide for transportation officials to create traffic signal systems in accord with the National ITS Architecture. It provides reasons why this is important, as well as implementation techniques.
FHWA. Improving Traffic Signal Operations Primer. 1995. www.itsdocs.fhwa.dot.gov/\JPODOCS\REPTS_TE/13466.pdf.	This is a general information document about traffic signals.
FHWA. Incident Management Successful Practices/ Improving Mobility and Saving Lives. April 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/8v001!.pdf.	This document includes information related to incident management, including case studies.
FHWA. The Road to Successful ITS Software Acquisition. July 1998. "Executive Summary" (EDL #4132) - www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/36s01!.pdf "Volume I: Overview and Themes" (EDL #4103) - www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/36q01!.pdf "Volume II: Software Acquisition Process Reference Guide" (EDL #4131) - www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/36r01!.pdf	A how to manual for software acquisition.
FHWA. Wireless Shared Resources Sharing Right-of-Way for Wireless Telecommunications. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/41s01!.pdf.	This document includes case studies for cooperative agreements.
FHWA. Enhancing Public Safety, Saving Lives - Emergency Vehicle Preemption. http://www.itsdocs.fhwa.dot.gov/jpodocs/brochure/5@v01!.pdf.	A short informational brochure about emergency vehicle preemption that could increase awareness of the benefits of such a system.
FHWA. Results of the Arterial Management Survey. http://www.nawgits.com/fhwa/artmgt_survey.html.	Summary of traffic signal information survey.
National Associations Working Group (NAWG). The National Associations Working Group for ITS Website. http://www.marc.org/transportation/ogl/OGLdocs.htm.	Useful link to major organizations working together for ITS.

Resource	Summary
ITS America. Another Offering of CITE's VERY Successful "Blended" Traffic Signal Timing Course. January 20, 2004. http://www.itsa.org/ITSNEWS.NSF/0/0aca0289f4642c1a85256e2100717884?OpenDocument.	Description of a successful traffic signal timing education course. The course provides students with an understanding of both the theory and practice of traffic signal timing and its impact on traffic operations. It gives students an overview of the terms associated with signal timing; discusses the concepts of cycle length, split, offset, midblock friction, phase sequences, the signal timing process, and signal timing optimization; and looks at the types of actuated controllers, passage time, extension, and the coordination of actuated and pretimed controllers. It also discusses the development of timing plans, explores types of signal control (first generation control and advanced techniques, including Rhodes, RT-TRACS, SCAT, and SCOOT) and investigates the relationship of signal timing to ITS: regional and system/design considerations.
National Institute for Advanced Transportation Technology. Traffic Signal Summer Camp. November 2001. http://ntl.bts.gov/data/KLK205.pdf.	A report of an experimental summer camp to teach students advanced traffic signal control hardware and software that is being examined for applicability to practicing traffic engineers. Traffic Signal Summer Camp included the following activities: • Introduction to traffic signal capacity analysis • Introduction to traffic signal simulation models • Development and testing of a signal timing design for a fixed time controller • Development and testing of a signal timing design for an actuated traffic signal controller using a Controller Interface Device • Construction and testing of a loop detector • Design and testing of a video-based traffic detection plan
US Department of Transportation. ITS Deployment Tracking: 2002 Survey Results. http://itsdeployment2.ed.ornl.gov/its2002/default.asp.	This site provides access to information on the deployment and integration of ITS technology gathered through a series of nationwide surveys, beginning in 1996 and continuing to 2002. This site contains the latest update to the data from a survey of over 2200 state and local agencies carried out in 2002.
FHWA. Intelligent Transportation Systems Benefits and Costs 2003 Update. May 2003. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13772.html.	The increasing demand for travel by highway and public transit in the United States is causing the transportation system to reach the limits of its existing capacity. Intelligent Transportation Systems (ITS) can help ease this strain through the application of modern information technology and communications. This report is a continuation of a series of reports providing a synthesis of the information collected by the United States Department of Transportation's ITS Joint Program Office on the impact that ITS projects have on the operation of the surface transportation network. New in this 2003 report is the inclusion of cost information for representative ITS deployments; previous reports contained only benefits information. Information in this report is drawn from the ITS Benefits and Unit Costs Database, a regularly updated repository of such information, available on the Internet at www.benefitcost.its.dot.gov. The report presents material from the database that describes the impacts and costs of the intelligent transportation infrastructure as well as intelligent vehicle applications.

Key Links

Resource	Summary
FHWA. 2003 ITS/Operations Resource Guide. Systems Operations Section. http://www.its.dot.gov/JPODOCS/catalog/system.htm	The 2003 ITS/Operation Resource Guide is a list of resources related to ITS and system operations. These include points of contact, websites, articles, training, databases, and others.
Transportation Research Board. Traffic Signal Systems webpage. http://signalsystems.tam.	This website links to the TRB's traffic signal systems committee page. This site contains information about specific signal technologies. It contains particularly extensive information about conference topics of transit preemption and adaptive signal control.
ITS America. Transit Signal Priority webpage. http://www.itsa.org/tsp.html.	Links to articles and information about Transit Signal Priority from ITS America.
US Department of Transportation. National Transportation Library. http://ntl.bts.gov/	Contains a plethora of information related to all fields of traffic signals, including Traffic Signals. Many resources from this site were utilized, but not every one of the nearly 3,000 articles were examined for this study. When searching for specific literature, however, can prove invaluable.

Case Studies

Resource	Summary
Minnesota Department of Transportation. Integrated Corridor Traffic Management. April 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9xb01!.pdf. ***Key Resource***	The concept of Integrated Corridor Traffic Management was to optimize corridor capacity, traffic operations, and safety by the application of a myriad of advanced technologies including adaptive ramp metering, adaptive, traffic signals, motorist information, and surveillance systems. This was done with a corridor wide approach in a case study in Minnesota.
Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/OGLdocs.htm. ***Key Resource***	Examination of traffic signals for the Kansas City Area. It gives brief synopses of Traffic signal operations in Denver, Las Vegas, and Houston. It included information on how jurisdictional and funding matters were handed in these metropolitan traffic signal systems.
FHWA. San Antonio's Medical Center Corridor: Lessons Learned From the Metropolitan Model Deployment Initiative. http://www.nawgits.com/jpo/lib/13220.pdf. ***Key Resource***	Case study of integrated freeway and arterial management in San Antonio. It contains examples of institutional changes, public/private partnerships, and impacts.
FHWA. Cross-Jurisdictional Signal Coordination in Phoenix and Seattle. http://www.nawgits.com/jpo/lib/13222.pdf. ***Key Resource***	Case study of municipal cooperation for arterial management in Phoenix with a brief synopsis of similar efforts in Seattle. Part of the AZTech Metropolitan Model Deployment Initiative (MMDI) effort was to coordinate traffic signals across jurisdictions in the East Valley of Phoenix. That signal integration helped form Smart Corridors that allow smooth progressions across jurisdictions.
Minnesota Department of Transportation. Evaluation of Non-Intrusive Technologies for Traffic Detection Website. http://projects.dot.state.mn.us/nit/.	This website provides up-to-date results from the Minnesota DOT and FHWA's Evaluation of Non-Intrusive Technologies for Traffic Detection.
Minnesota Department of Transportation. Adaptive Urban Signal Control and Integration. October, 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@@n01!.pdf.	Case study evaluation in the Minneapolis CBD. The AUSCI project encompasses a 56-intersection portion of the Minneapolis CBD. The Split Cycle Offset Optimization Technique (SCOOT) system was selected to provide the adaptive control. AUSCI integrates the SCOOT system with the original Urban Traffic Control (UTC) system, allowing the operator to select which control strategy to implement. The project is unique because 138 video sensors provide the system's detection requirements.

Resource	Summary
AASHTO. Maine's Statewide Traffic Signal Bulb-to-LED Replacement Program. 2002. www.transportation.org/aashto/success.nsf/allpages/2003-14maine.	Description of Maine's Traffic Signal Replacement Program to improve traffic signal technology and energy efficiency.
Public Technologies, Inc. Traveling with Success: How Local Governments Use Intelligent Transportation Systems: On the Fast-Trac to Economic Health-- Oakland County, Michigan. http://pti.nw.dc.us/task_forces/transportation/docs/success/travel31.htm.	Case study of Oakland County, Michigan reported to be the largest operational test of intelligent transportation systems in the world. At the core of traffic management is the Sydney Coordinated Adaptive Traffic System (SCATS), which operates traffic signals in real time and adjusts them automatically to reflect changes in traffic flow, incidents, and accidents.
Abdel-Rahim, A. and W. Taylor. Analysis of Corridor Delay Under SCATS Control. April 1998. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/75v01!.pdf.	This study was designed to determine the change in travel time following the implementation of the Sydney Coordinated Adaptive Traffic System (SCATS) in Oakland County, Michigan. A before/after comparison was used to examine the change in travel time on a specific corridor (Orchard Lake Road). The results of the study showed that corridor travel-time and intersection delay for the main street through traffic improved as a result of SCATS implementation. The corridor travel-time improved for both directions for both the peak and the non-peak periods. The reduction in corridor travel time ranged from 6.56% to 31.80%, with savings in travel time being higher during the non-peak periods.
ITS America. Georgia Governor Announces "Fast Forward Transportation" Program. April 2004. http://www.itsa.org/ITSNEWS.NSF/0/c7d6a919d46ebfe685256e770008b8e3?OpenDocument	Article describes ITS initiatives in Georgia.
ITS America. NCDOT Requests Input On Web Site Design. March 2004. http://www.itsa.org/ITSNEWS.NSF/0/08072ef01e0d0d7985256e5500536ac2?OpenDocument.	An article detailing NCDOT's efforts to share data on a website.
ITS America. LA County Shares Signals Online. July 2002. http://www.itsa.org/mn.nsf/0/e077abcf982e1d1b85256bdf006f4308?OpenDocument.	Los Angeles case study of Traffic Management Center and a traffic signal linking project.
ITS America. VDOT Using Information Technology to Keep Virginia Moving. May 1999. http://www.itsa.org/itsnews.nsf/0/d010544dbacfe26e8525676a00684720?OpenDocument.	This article describes three of Virginia DOT's (VDOT) technology initiatives including smart signals. In May 1999, VDOT re-timed 40 intersections in the heavily congested Tyson's Corner area of Northern Virginia to smooth traffic flow and reduce travel time. The work is part of VDOT's ongoing traffic signal program to improve signal coordination at 800 intersections in Northern Virginia.
Road Commission for Oakland County, Michigan. Lifecycle Costs Case Study Summary. www.itsa.org/subject.nsf/Files/CaseStudyFAST-TRAC/$file/CaseStudyFAST-TRAC.doc.	A brief description of the FAST-TRAC project in Oakland County, Michigan including costs and lessons learned.
ITS America. Successful ATMS/NTCIP Center To Field Integration In Phoenix And Lakewood. November 2001. http://www.itsa.org/ITSNEWS.NSF/0/5f9691841324f16f85256af70042a693?OpenDocument.	A brief description of the public private partnership in Phoenix and Lakewood, Colorado. Phoenix and Lakewood are the first Cities in the world to develop a fully operational, multi-bandwidth, field deployed system that implements the new communication protocol, National Transportation Communications for ITS Protocol (NTCIP).
ITS America. Georgia ATMS Recognized for Excellence. February 1, 2000. http://www.itsa.org/itsnews.nsf/0/8a9ceab75f252a77852568790068261f?OpenDocument.	Description of award winning Traffic Control Center (TCC) and Advanced Traffic Management System (ATMS) in Cobbs County, GA.

Resource	Summary
ITS America. Siemens to Install Statewide Traffic Signal System. February 2002. http://www.itsa.org/itsnews.nsf/0/a864c8f68174a2e985256b5d007fc87b?OpenDocument.	Article describing Arizona DOT's (ADOT) contract with Siemens GTS to install icons[tm] advanced traffic management systems statewide. ADOT led a multi-agency selection committee that evaluated competitive proposals to come to their decision. The intent is for the system to be made available to agencies in Arizona for the operation of traffic signal systems throughout the State.
King, Dale M. Smart Signals. Boca Raton News. May 26, 2004. http://www.bocaratonnews.com/index.php?src=news&prid=8426&category= LOCAL%20NEWS&PHPSESSID=888c635c174e11df5f65a6e0f521b457	A description of Boca Raton's Smart Signals System.
Warren, John. Beach Traffic Signals May Soon Be In Sync With Traffic. The Virginian-Pilot. March 6, 2004. http://home.hamptonroads.com/stories/story.cfm?story=67099&ran=167160.	Description of the ITS system in Virginia Beach.
ITS America. MTA, County DPW Win Award for Information Network. December 2, 2002. http://www.itsa.org/ITSNEWS.NSF/0/068c0ef4194887be85256c8d0047926e?OpenDocument.	Description of MTA and LA County Department of Public Works award winning traffic signal control program.
Jensen, M. et al. Metropolitan Model Deployment Initiative Seattle Evaluation Report: Final Draft. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@3301!.pdf.	The Metropolitan Model Deployment Initiative (MMDI) Seattle Evaluation Report describes the impacts on various benefits measures as a result of seven ITS projects undertaken through the deployment initiative. The projects included improvements in traveler information, traffic signal control, and transit information dissemination. The Seattle metropolitan area had a considerably high level of ITS implementation prior to the MMDI projects, therefore the experiences of localities implementing these systems under differing conditions may vary significantly from those reported in Seattle.
Maryland Department of Transportation. Charting your course : Maryland CHART program. http://www.itsdocs.fhwa.dot.gov//JPODOCS/BROCHURE/1Z901!.PDF.	CHART (Chesapeake Highway Advisories Routing Traffic) is a joint effort of the Maryland Department of Transportation and the Maryland State Police, in cooperation with other federal, state and local agencies. CHART's mission is to improve "real time" operations of the highway system through teamwork and technology. CHART is comprised of four basic components: (1) surveillance (detection of what is happening at every moment on all major parts of the highway system); (2) incident response (working with law enforcement, fire and other emergency response agencies to remove blockages safely and quickly); (3) traveler information (alerting users to unusual problems that are disrupting the flow of traffic): and (4) traffic management (managing to cope with incidents through signs, signals and other traffic control measures). CHART uses a balance of high and low technology, from TV cameras to tow trucks.

Resource	Summary
TRB Traffic Signal Systems Committee. Signal Systems Committee Triennial Strategic Plan. March 22, 2004. http://signalsystems.tamu.edu/documents/Triennial2004/Strategic_Plan.pdf.	The Traffic Signal Systems Committee Strategic Plan was developed in the early 1990's. Based on the Strategic Plan, the Committee adopted an Action Plan which has been updated periodically, and at last count contained 14 activities. An assessment of the Committee's achievements relating to these activities was completed at the 2003 Summer Meeting. In general, the consensus was that we have done fairly well accomplishing many of our objectives. The summer meeting workshops and the workshops at the Annual meeting have been a strength of the Committee during the last five years including providing the materials on the Committee web site.

Phase II Follow-ups

Resource	Summary
FHWA. Current Program Activities Website. http://ops.fhwa.dot.gov/program_areas/progmactiv.htm.	This page includes information about FHWA Office of Operations projects that are programmed, but not yet completed. This page is updated quarterly and includes program titles consistent throughout the Office of Operations. The titles included are: Non-recurring Congestion (Traffic Incident Management, Work Zone Management, Road Weather Management, and Special Events Traffic Management); Recurring Congestion (Arterial Management, Corridor Traffic Management, Freeway Management, and Travel Demand Management); Day to Day Operations (MUTCD, Operations Asset Management, Real Time Traveler Information, and Traffic Analysis Tools); Creating a Foundation for 21st Century Operations (RTOCC, Performance Measurement, and Facilitating Integrated-ITS Development); Improving Global Connectivity by Enhancing Freight Management and Operations (Freight Analysis, Freight Professional Development, Freight Size and Weight, and Intermodal Freight Technology); and Improving Mobility and Security Through Better Emergency Management (Emergency Transportation Operations).
National Cooperative Highway Research Program - Anticipated Project. Integrated Control for Improved Operation of Freeways and Surface Streets in Urban Corridors. http://www4.trb.org/trb/crp.nsf/0/fc11e67c2ce30aad85256e8200504ad0?OpenDocument.	The objectives of this project are to research methods of integrating the control of freeway and traffic signal control systems and to develop a technical reference that provides guidance and recommended practices on integrating control of these systems. Integrating the control of freeway and traffic signal control systems, within the same urban corridor, allows for the implementation or modification of the operational strategies and traffic control plans in response to changing roadway conditions. Integrated control provides the capability for agencies to proactively manage and control traffic to improve travel on a specific roadway, at a series of intersections controlled by traffic signals, at interchange ramp terminals, or within an urban corridor where travel occurs on alternative freeways and surface streets. This project has been tentatively selected and a request for proposals is expected in September 2004.
ITE. State of the Practice in Traffic Engineering.	An examination of the State of the Practice in Traffic Engineering, including traffic signals.[109]

Resource	Summary
FHWA. Case Studies for Regional Traffic Signal Timing. http://ops.fhwa.dot.gov/program_areas/progmactiv.htm#ii.	The intent of project is to develop case studies on the successes and struggles of inter-jurisdictional traffic signal programs and to provide FHWA Office of Operations with case studies of regional traffic signal timing programs that can be provided to client agencies and transportation partners as a model, guide, or framework for establishing a successful program. Completion anticipated August 2004. Numerous areas throughout the country are benefiting from traffic signal coordination within its own communities and increasingly across jurisdictional boundaries into neighboring communities. Experience shows that interconnecting traffic signals and optimizing the traffic signal timing can result in travel time reductions ranging from 8-25 percent along a corridor or arterial. The most important factor in achieving coordination across jurisdictional boundaries is cooperation and communication among agencies. The greatest achievement of cross-jurisdictional coordination of traffic signal timing is when it is performed for a region. There are State DOTs, MPO/RPOs, and other transportation organizations that have in the past or are currently developing regional traffic signal timing programs.
FHWA. Training Assessment.	An effort to look at knowledge, skills, and abilities required by differing levels of traffic signal operators and traffic engineers. It will then suggest workshops and courses from public and private sources to be completed at appropriate times in the career of individuals dealing with traffic signals.FHWA will assess all of the existing courses that are designed for signal technicians and traffic engineers. Next, a gap analysis will be performed to see where there are missing training and courses available. This initiative was begun in August 2004.When the existing courses are listed and categorized by the knowledge, skills and abilities of the signal technicians and traffic engineers, they will be posted to the FHWA website. It is anticipated that this will continue through February 2005.[110]
National Transportation Operations Coalition. Traffic Signal Timing Road Map. http://www.ite.org/selfassessment/faq.asp.	The Traffic Signal Timing Road Map is an effort to look for gaps in the current traffic signal systems. A Traffic Signal Systems Self Assessment survey will lead to a state of Traffic Signals grading system similar to that used for bridges. Organizations will be able to grade themselves anonymously and results will be anonymous as well. Results of this program should be available in February, 2005. The NTOC will use the results of the survey to create a national report card on the current state of traffic signal operations. The national report card is intended to bring national awareness to the need for increased investment in signal operations. Moreover, local officials can evaluate the strengths and opportunities of ongoing signal operations. Evaluation results can be used for planning program and communicating plans and resource requirements.[111]

Resource	Summary
FHWA, Signal Systems Asset Management State-of-the-Practice Review - RELEASED 08/13/04 http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE/13993.html	The FHWA Office of Transportation Management has undertaken the Investigation of Signal System Assets Management Methodology and Process Elements project, Task Order Number CA81F042. The purpose of this project is to obtain a better understanding of operations-level asset management by examining the specific case of signal systems. Twenty-six state, county, and local agencies were surveyed regarding lane miles, number of signals, and signal system budgets for construction, maintenance, and operations. FHWA also surveyed the uses and types of signal management software tools currently being utilized. Results indicate that agencies are tracking and managing the physical, systems and personnel components of their signal systems at varying levels of sophistication, as appropriate to the scale and complexity of their systems. Tools and techniques are in place to optimize system performance for the road user; most agencies track performance of intersections or groups of intersections with respect to safety and delay; and use this information to identify improvement needs. As agencies upgrade signal management technologies, new real-time capabilities for performance monitoring and control will come on-line which will allow further performance gains to be realized. With respect to the physical aspect of signal systems, most agencies have basic inventory tracking and maintenance management systems, but relatively few maintain data on failure rates and historical repair costs that would be needed to make a case for doing more preventive (versus reactive) maintenance. This type of data would also be needed to develop predictive capabilities in support of performance-based budgeting approaches. Given the agencies' concerns with respect to budgetary and staff limitations and their desire to reduce repair costs, improved capabilities to both prioritize investments and to demonstrate what could be achieved with additional resources would be valuable. Agencies are considering tradeoffs between technology and staff resources, and the application of asset management principles will increase the sophistication of this analysis. The detailed case studies conducted in the next phase of the project will help identify asset management tools and practices that will meet agency needs.

Resource	Summary
ITE, Traffic Signal Timing State of the Practice	A new ITE report that will become available in October 04, Traffic Signal Timing State of the Practice, concludes that many transportation agencies in the U.S. are using sub-optimal approaches to traffic signal control, and recommends three key remedies. The ITE-sponsored study on which the report is based involved both a user survey as well as extensive literature search. 117 survey responses were received from all levels of government. Three overriding recommendations for closing the identified gap between the state-of-the-practice and state-of-the-art: (1)More resources are needed by agencies responsible for traffic control systems. (2)Training and education are needed to help make signal system engineers more aware of the state-of-the-art. (3)Additional standardization and knowledge are needed in key areas.
The Smaller MPO/RPO as a Catalyst in Transportation Operations A discussion with Bob Kamm, Director Brevard County (FL) Metropolitan Planning Organization http://www.nawgits.com/icdn/MPO/RPO_as_catalyst.html	This interview and presentation outlines how a medium-sized MPO/RPO implemented a Traffic Operations program. As a result of stagnant funding and fragmented Traffic Operations, the MPO/RPO identified priority projects for Traffic Operations in the County. Utilizing state gas taxes and federal Urban Attributable funds under MPO/RPO programming control, Brevard County has approximately $1.1 million set aside for priority Traffic Operations. Projects are decided primarily based upon locations where the volume/capacity (V/C) ratio exceeded 85%. A Traffic Operations Committee (TOC) comprised of senior staff of local agencies and Florida DOT meets quarterly to identify priorities, expedite implementation, and enhance communication. Projects selected are mainly based on signal coordination.
NCHRP REPORT 500 SUBJECT AREAS Safety and Human Performance Guidance for Implementation of the AASHTO Strategic Highway Safety Plan Volume 12: A Guide for Reducing Collisions at Signalized Intersections http://www.trb.org/publications/nchrp/nchrp_rpt_500v12.pdf	As an element of AASHTO's Strategic Highway Safety Plan, this guide provides 28 engineering specific strategies to reduce collisions at signalized intersections. Moreover, the guide identifies which strategies are proven, tried, and experimental. The guide encourages a comprehensive approach to highway safety problems associated with signalized intersections and recommends strategies for public information and education programs, enforcement of traffic laws, improvement to emergency medical and trauma system services, improvement to safety management system and other strategies for pedestrians, bicyclists, and older drivers.

APPENDIX E

Endnotes

Endnotes
Summary of References

[1] (Mr. 'Trafficlight' by Sheldon Moyer, 1947 Motor News).
[2] (http://www.prinsfamily.com/David/trafficsignals/history.html)
[3] . (Museum archives, Henry Ford Museum & Greenfield Village (as of Jan 29 2003)
[4] (http://www.prinsfamily.com/David/trafficsignals/history.html)
[5] www.signalfan.com
[6] FHWA Table HM10 -2001 data
[7] Bureau of Highway Safety and Traffic Engineering Traffic Signal Database, 2004..
[8] National Association of Development Organizations, Regional Transportation Online Center, Pennsylvania: The Rural Context for Transportation Consultations, 2004.
[9] Southwestern Pennsylvania Commission, "Traffic Signal Opportunities for Southwestern Pennsylvania," June 1996.
[10] Bureau of Highway Safety and Traffic Engineering Traffic Signal Database, 2004.
[11] Ibid.
[12] Pennsylvania General Assembly, Legislative Budget and Finance Committee, A Review of Traffic Congestion Trends and Related Mitigation Efforts, September 2001.
[13] Ibid.
[14] Personal Interview with Charles J. Trainer III, Chief Traffic Engineer, Philadelphia Department of Streets, July 22, 2004.
[15] Email from Paul K. Cornell, Administrator, Swatara Township, July 30, 2004.
[16] Lillian Thomas, "City's traffic expert laid off," Pittsburgh Post-Gazette, January 27, 2004, http://www.post-gazette.com/pg/04027/266073.stm (8 November 2004).
[17] 75 PA. CONS. STAT. §9004(a)
[18] 75 PA. CONS. STAT. §9010(c)
[19] 75 PA. CONS. STAT. §9010(b)(2)(i)(e)
[20] A Review of Traffic Congestion Trends and Related Mitigation Efforts, September 2001.
[21] Letter from Gary L. Hoffman, P.E., Acting Deputy Secretary for Highway Administration, Pennsylvania Department of Transportation to All District Engineers/Administrators, No Date.
[22] 36 PA. CONS. STAT. §670.
[23] McCourt, Ransford S., "Traffic Signal Maintenance and Design Survey," DKS Associates, ITE District 6 Annual Meeting, 1996.
[24] Ibid.
[25] Ibid.
[26] Traffic Signal Opportunities for Southwestern Pennsylvania, June 1996.
[27] Ibid.
[28] Southwestern Pennsylvania Regional Planning Commission, Survey of Municipal Traffic Signal Practices, March 1996.
[29] Weisbrod, Glen, Measuring the Economic Costs of Urban Traffic Congestion to Business, Economic Development Research Group, TRB 2003 Annual Meeting, November 2002.
[30] Paniati, Jeff, Acting Associate Administrator, Federal Highway Administration, Office of Operations, Traffic Congestion and Sprawl - Press Club Event, November 19, 2002.
[31] Ibid.
[32] Schrank, David and Tim Lomax, Texas A&M University, Texas Transportation Institute, The 2003 Annual Urban Mobility Report, September 2003.
[33] Federal Highway Administration, Office of Operations (HOP), Congestion Mitigation, 2003.
[34] Transportation Research Board, Economic Impacts of Congestion, NCHRP Report 463, 2001.
[35] Ibid.
[36] Ibid.
[37] Ibid.
[38] Ibid.

[39] Federal Highway Administration, Highway Statistics 2002: Selected Measures for Identifying Peer States - Table PS-1, October 2003.
[40] Bureau of Highway Safety and Traffic Engineering, 2004.
[41] Traffic Signal Opportunities for Southwestern Pennsylvania, June 1996.
[42] Dan Weisberg, P.E., "Telephone Interview with Director, Palm Beach County Department of Engineering and Public Works, Traffic Division," August 2, 2004.
[43] Telephone Interview with Cheryl Lambert, Traffic Engineer, Kansas Department of Transportation, Division of Operations, Bureau of Traffic Engineering, August 5, 2004.
[44] Telephone Interview with Tim Crouch, P.E., State Traffic Engineer, Iowa Department of Transportation, Office of Traffic and Safety, August 5, 2004.
[45] Telephone Interview with Steven Kohan, Traffic Engineer, Maryland Department of Transportation, State Highway Administration District 3, August 4, 2004.
[46] Telephone Interview with David Anderson, Transportation Planner, Delaware Valley Regional Planning Commission, August 4, 2004.
[47] Telephone Interview with Mark Pyskadlo, Traffic Engineer, New York State Department of Transportation Region 1, Traffic and Safety Department, August 4, 2004.
[48] Telephone Interview with Karim Yousuf, Assistant Traffic Engineer, Nevada Department of Transportation, District 1, August 5, 2004.
[49] Telephone Interview with Bill James, Traffic Engineer, Ohio Department of Transportation, Office of Traffic Engineering, August 5, 2004.
[50] Telephone Interview with Heath Hoftiezer, Traffic Engineer, South Dakota Department of Transportation, Road Design Division, August 5, 2004.
[51] Telephone Interview with Mike Brown, Traffic Engineer, Tennessee Department of Transportation, Region 3 - Traffic Engineering, August 6, 2004.
[52] ITS America. Georgia Governor Announces "Fast Forward Transportation" Program. April 2004.
[53] Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/OGLdocs.htm. Section 2.4, Pg. 12.
[54] Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/OGLdocs.htm. Section 2.3, Pg. 8.
[55] Ibid.
[56] Ibid.
[57] Ibid.
[58] Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/OGLdocs.htm. Section 2.2, Pg. 4.
[59] Ibid.
[60] Minnesota Department of Transportation. Integrated Corridor Traffic Management. April 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9xb01!.pdf. Pg. 14
[61] Ibid.
[62] Minnesota Department of Transportation. Integrated Corridor Traffic Management. April 2000. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/9xb01!.pdf. Pg. 2
[63] Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/OGLdocs.htm. Section 2.2, Pg. 4.
[64] Ibid.
[65] Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/OGLdocs.htm. Section 2.3, Pg. 8.
[66] ITS America. LA County Shares Signals Online. July 2002. http://www.itsa.org/mn.nsf/0/e077abcf982e1d1b85256bdf006f4308?OpenDocument..
[67] FHWA. Cross-Jurisdictional Signal Coordination Case Studies. February, 2002. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html.
[68] Ibid.
[69] Ibid.
[70] AASHTO. Maine's Statewide Traffic Signal Bulb-to-LED Replacement Program. 2002. www.transportation.org/aashto/success.nsf/allpages/2003-14maine.

[71] Mid-America Regional Council. Operation Green Light. http://www.marc.org/transportation/ogl/OGLdocs.htm. Section 2.2, Pg. 5.
[72] Jensen, M. et al. Metropolitan Model Deployment Initiative Seattle Evaluation Report: Final Draft. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@3301!.pdf.
[73] http://131.193.92.223/research/one/rtasignal.html

[74] http://www.itsa.org/mn.nsf/0/e077abcf982e1d1b85256bdf006f4308?OpenDocument
[75] http://www.cityoforlando.net/public_works/traffic/tmc.htm
[76] (2002) *Cross-Jurisdictional Case Studies* FHWA. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html#_Toc658843
[77] U.S. Department of Transportation, "Cross-Jurisdictional Signal Coordination in Phoenix and Seattle: Lessons Learned from the Metropolitan Model Deployment Initiative," http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/@7@01!.PDF (8 November 2004).
[78] U.S. Department of Transportation. *San Antonio's Medical Center Corridor: Lessons Learned from the Metropolitan Model Deployment Initiative.*
http://www.its.dot.gov
[79] http://www.marc.org/transportation/ogl/feasibility-section2.pdf
[80] http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html#_Toc658844
[81] www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/projects/TTM-416.htm
[82] Maricopa Association of Governments, *Regional Concept of Transportation Operations*, November 2003.
[83] (2004)NEPA Receives PennDOT Approval for Two Congested Corridor Studies http://www.tristatenews.com/printer_2677.stm
[84] http://www.odot.state.or.us/traffic/trafoper.htm
[85] http://murray.senate.gov/news.cfm?id=220486
[86] http://www.ci.austin.tx.us/news/traffic_signals.htm
[87] Rogue Valley Council of Governments, *2001-2023 Rogue Valley Regional Transportation Plan*, April 2002.
[88] Institute of Transportation Engineers and the Federal Highway Administration, *What is a Road Safety Audi?*, http://www.roadwaysafetyaudits.org (Oct. 15, 2004)
[89] Ibid.
[90] Institute of Transportation Engineers and the Federal Highway Administration, *Executive Summary*, http://www.roadwaysafetyaudits.org (Oct. 15, 2004)
[91] Carol Zimmerman, Mala Raman, William J. Mallett, and Craig Roberts, Sharing Data for Public Information: Practices and Policies of Public Agencies, Washington, DC: U.S. Department of Transportation, January 2002, http://www.ops.fhwa.dot.gov/Travel/DatShare.htm (Oct. 15, 2004).
[92] New York Department of Transportation, *Transportation Management Equipment Qualified Products List*, August 2004, http://www.dot.state.ny.us/traffic/files/qpl.pdf (Oct. 18, 2004).
[93] New Jersey Department of Transportation, *Research- Final Reports,* http://www.state.nj.us/transportation/refdata/research/ReportsDB.shtm (Oct. 18, 2004).
[94] Ohio Department of Transportation, *Design Reference Resource Center,* http://www.dot.state.oh.us/drrc/ (Oct. 18, 2004).
[95] http://www.city.vancouver.bc.ca/ctyclerk/cclerk/20030513/tt1.htm
[96] City of Springfield. Eighth-cent Transportation Tax. http://www.ci.springfield.mo.us/egov/eighthcent.html
[97] California Energy Commission. *Gasoline Taxes by State 2002.* http://www.energy.ca.gov/gasoline/statistics/gas_taxes_by_state_2002.html
[98] New York Newsday. Group pushes tax hike for Lake County roads. http://www.nynewsday.com/travel/chi-0402120269feb12,0,7074045.story?coll=sns-travel-headlines
[99] Summary of the Transportation Strategic Plan Public Involvement Process, Seattle Transportation. http://www.ci.seattle.wa.us/transportation/pdf/appendxb.pdf
[100] (1996) Financing Pennsylvania's Local Roads. Pennsylvania Department of Transportation Local Government Transportation Finance Task Force
http://www.dot.state.pa.us/Internet/SECINET.nsf/infoLGTFTF?OpenForm

[101] American Association of State Highway and Transportation Officials, Freight Transportation Network, *Freight Transportation: The European Market*, June 2002.
[102] Sacramento Municipal Utility District, *LED Traffic Signals*, http://www.smud.org/education/led.html (Oct. 15, 2004).
[103] Governor's Center for Local Government Services, Land Use Planning and Technical Assistance Program, *Program Guidelines*.
[104] Federal Highway Administration, United States Department of Transportation, *Getting More by Working Together- Opportunities for Linking Planning and Operations* ,September 10, 2004.
[105] Federal Highway Administration, United States Department of Transportation, *Cross-jurisdiction Signal Coordination Case Studies,* February 2002, http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/13613.html (Oct. 15, 2004).
[106] Mid-America Regional Council, *Operational Green Light,* http://www.marc.org/transportation/ogl/ (Oct. 15, 2004
[107] Mid-America Regional Council Operation Green Light http://www.marc.org/transportation/ogl/OLGdocs/htm.
[108] http://www.tfhrc.gov/pubrds/novdec98/its.htm
[109] Telephone interview with Pam Crenshaw, Program Manager, FHWA, July 23, 2004.
[110] Telephone interview with Pam Crenshaw, Program Manager, FHWA, July 23, 2004..
[111] Telephone interview with Pam Crenshaw, Program Manager, FHWA, July 23, 2004.