MAINTENANCE-IQ
- Making Maintenance Easy -

2017 URISA ESIG™ AWARD
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Section A. System

1. Name of System and ESIG™ category

Name of System: Maintenance-IQ

Category: Enterprise Systems

This award application is proudly submitted by the system owner, the Pennsylvania Department of Transportation (PennDOT), Bureau of Maintenance and Operations, in collaboration with the system development and geospatial consultant, GeoDecisions.
June 1, 2017

URISA ESIG Awards
701 Lee Street, Suite 680
Des Plaines, IL 60016

Dear Selection Committee:

The Pennsylvania Department of Transportation (PennDOT) is pleased with the outstanding work of GeoDecisions, and hereby grants permission to enter the Maintenance-IQ application development project into the 2017 URISA ESIG Award for Enterprise Systems competition.

We partnered with GeoDecisions to develop Maintenance-IQ, a web-based geographic information system (GIS) that improves PennDOT’s maintenance planning and scheduling throughout the Commonwealth of Pennsylvania. GIS mapping enables PennDOT staff to better integrate, analyze, and visualize data from multiple sources.

A huge advantage for us, Maintenance-IQ users can drag, drop, and generate Roadway Management System (RMS) and latitude/longitude-based spreadsheets through a PennDOT extract, translate, and load (PETL) plug-in. Maintenance-IQ allows novice users to easily access complex data, along with 10+ other source systems, and retrieve information necessary for funding, business planning, project design, and maintenance programming decisions. Before Maintenance-IQ, it took several days to produce maps. Now, required maps can be produced in minutes.

An example of a true benefit, Maintenance-IQ template maps help PennDOT eliminate out-of-sequence rework (i.e., preparatory work activities such as widening, base repair, pipe replacement, patching, shoulder cutting, and crack sealing that are scheduled shortly after a surface improvement project). This level of visual analysis enables PennDOT maintenance crews to advance the work activity or delay the surface improvement project to prevent unnecessary and costly re-work.

A more efficient process saving PennDOT time and money, Maintenance-IQ is a geospatial solution built on reusable code that reflects our ongoing commitment to enterprise GIS technologies. The application enhances our public services with actionable data achieved through improved maintenance operations. Improved asset and infrastructure management translates to safer roads and smoother commutes.
As the owner, we appreciate the hard work and dedication of GeoDecisions’ Maintenance-IQ project team located at our Harrisburg, Pennsylvania, headquarters. From application design, development, and implementation to hands-on PennDOT user training throughout the state, GeoDecisions’ level of service was exemplary.

More than 400 Maintenance-IQ users participated in GeoDecisions-driven training, including county managers, maintenance assistant managers, roadway program coordinators and technicians, district managers and program coordinators, and Central Office staff. Feedback has been unanimous.

We wholeheartedly endorse the publication of this project, its unique features, and its innovations. Thank you for your favorable consideration.

Should you have any questions, please contact Shawn Crane, Section Chief – Maintenance Systems and Reporting, at (717) 787-7907.

Sincerely,

Shawn P. Crane
Pennsylvania Department of Transportation
Chief, Maintenance Systems and Reporting Section
3. Summary of the System

Maintenance-IQ serves as a nationwide model for state departments of transportation when using geospatial technology to efficiently plan and schedule maintenance activities, new construction, and grant projects. The application allows PennDOT to effectively use geographic information system (GIS) mapping to strategically connect with a long-term enterprise IT plan, while producing immediate and beneficial infrastructure project results that enhance collaboration and save time and money.

Tasked with maintaining more than 40,000 miles of state roads and more than 25,000 bridge structures, PennDOT needed a better way to manage improvement projects. With mounds of maintenance-relevant data stored in disconnected technology silos throughout 67 counties and 11 engineering districts, it was a hardship for PennDOT staff members to find, decipher, or communicate information quickly. GeoDecisions created a dynamic, custom GIS application, coined “Maintenance-IQ,” to transform how PennDOT plans and schedules maintenance activities.

Empowering PennDOT staff members and other transportation stakeholders to analyze, visualize, and share statewide infrastructure data, Maintenance-IQ combines information from more than 10 separate PennDOT technology systems. With actionable intelligence delivered through the application’s intranet-based GIS repository, PennDOT’s maintenance community is better-equipped to map planned and completed improvement projects, understand road and bridge assets and conditions, and prevent unnecessary and costly re-work.

Menu-driven and user-friendly, Maintenance-IQ is built with GIS technology that can be used by maintenance and non-maintenance PennDOT groups with GIS needs. At the core of the agency’s enterprise technology initiatives, Maintenance-IQ revolutionizes how PennDOT performs statewide planning and scheduling while providing nationwide departments of transportation with a GIS blueprint for better asset management.

Without a clear picture of the latest maintenance program data, PennDOT risked performing out-of-cycle assignments, such as replacing underground pipes after paving a road. Maintenance-IQ provided a GIS solution to tackle this and other problems.
4. User Testimonials

1. “More than 400 individuals were trained in Maintenance-IQ and the feedback has been incredible...new requests for functions and ideas are received daily, along with user testimonials on how the application is helping to get the job done.”

   Shawn Crane, Section Chief, Maintenance Systems and Reporting, PennDOT Bureau of Maintenance and Operations, and PennDOT Maintenance-IQ Project Manager

2. “Maintenance IQ is a tool that provides me the ability to put the power of GIS in the hands of those not formally trained in desktop GIS software. Instead of providing consumers with dated paper plots, I provide them working templates to create GIS products themselves and allow the user to use data to drive their business decisions. I use this tool daily to enlighten business sections of the available data at PennDOT and how other sections data affects business decisions within their own.”

   Matthew Long, Transportation Planning and GIS Specialist, PennDOT Center for Program Development and Management

3. “The work GeoDecisions has done with PennDOT staff in developing a user-friendly platform to create an endless series of custom GIS maps that assist with maintenance planning and asset management is outstanding.”

   Sandra Tosca, PE, PennDOT District Executive, PennDOT Engineering District 3-0

*Screenshot from the Maintenance-IQ application demonstrating a bridge and traffic data map with Google Street View integration.*
Section B. Jurisdiction

1. Name of Jurisdiction

Commonwealth of Pennsylvania, Pennsylvania Department of Transportation

2. Population Served by the Organization/Agency

Beneficiaries of the Maintenance-IQ system are Commonwealth of Pennsylvania Transportation Stakeholders, including PennDOT Central Office staff, Engineering District staff, County staff, MPO/RPO planning partners, contractors, and consultants. The monthly user base of the system is more than 300 users.

The Commonwealth of Pennsylvania is home to 12.8 million residents. PennDOT is responsible for maintaining one of the largest and heaviest-trafficked road networks in the United States.

3. Annual Total Budget for Jurisdiction

PennDOT’s initial investment in the Maintenance-IQ system was $600,000.00. PennDOT as a whole manages a budget of $8 billion annually.

4. Chief Elected and/or Appointed Official

The Honorable Scott Perry, United States Congress
800 North Third Street, Suite 301
Harrisburg, PA 17102
5. Contact Person for System

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Pennsylvania Department of Transportation
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Section C. System Design

1. Motivation for System Development

Responsible for the nation’s fifth largest state-maintained roadway network, PennDOT needed a better way to manage roadway improvement projects. With mounds of maintenance-relevant data stored in disconnected systems at multiple Commonwealth locations, it was a challenge for PennDOT bureau, district, and county staff members to find, decipher, or communicate information quickly.

Without a clear picture of the latest maintenance program data, PennDOT operations ran the risk of performing out-of-cycle assignments, such as replacing underground pipes after paving a road. This could result in delays, commuter frustration, and increased costs. PennDOT needed a solution to better manage data and enhance decision making while maintaining Pennsylvania’s aging infrastructure of roads and bridges and accommodating increased transportation network demands. PennDOT also wanted a faster way to deliver data and maps pertaining to maintenance issues to internal and external stakeholders.
2. Improving Services

Tasked with handling the roadway wear-and-tear from more than 225 million miles traveled every day throughout the Commonwealth, PennDOT Bureau of Maintenance and Operations staff needed a better way to manage improvement projects. Headquartered in Harrisburg, the Bureau’s central office oversees maintenance duties throughout the Commonwealth’s 67 counties, which are organized into 11 engineering districts.

Considering mounds of maintenance data stored in disconnected systems across the state, GeoDecisions worked with PennDOT to conduct information management system and user testing while assessing the agency’s maintenance planning, sequencing, operations, and technology integration needs. The team determined that transformative GIS technology was the answer. As a result, GeoDecisions created Maintenance-IQ, a custom application that empowers PennDOT staff to visualize, analyze, and map planned and completed infrastructure improvement projects and improve decision-making. Once Maintenance-IQ was deployed, GeoDecisions’ technology experts conducted statewide training for PennDOT staff to learn the system. GeoDecisions remains on-call for application support.

3. Unexpected Benefits

Reduced costs for Pennsylvania taxpayers is a positive outcome of PennDOT’s increased operational efficiency achieved through Maintenance-IQ. Because PennDOT maintenance staff members can better detect highway deficiencies, determine roadway treatments, plan operations, and monitor production, the traveling public realizes greater service and savings. Smoother highways result in reduced vehicle wear and tear and less pressure to increase fees and taxes that fund PennDOT. Application efficiencies also help PennDOT lessen traffic congestion, promote enjoyable commutes, lower vehicle carbon emissions, and support enhanced environmental compliance.

Using Maintenance-IQ, PennDOT personnel make more informed decisions that translate to better asset and infrastructure management and result in heightened transportation safety. A more efficient communication tool, the application expands infrastructure issue awareness while advancing geospatial excellence to PennDOT’s Bureau of Planning and Research and Innovations Office. Maintenance-IQ also enables PennDOT county and district users to deliver data and maps to legislators and outside stakeholders without waiting for a GIS analyst.
With wide-ranging benefits, Maintenance-IQ provides an application development roadmap that redefines the transportation GIS marketplace. It demonstrates how geospatial technology can reach a broader audience and provide self-sustaining, advanced tools through common code initiatives and dynamic services that achieve practical results. Utilizing a common code framework allows PennDOT to leverage individual system components across applications, minimizing overall application development costs.

4. Overcoming Design Problems

PennDOT has a highly advanced enterprise GIS that provides terabytes of data for use by Maintenance-IQ, the first application developed to harness this available data. Maintenance-IQ also provides access to unlimited external databases and map layers provided by other agencies and the public. Because PennDOT’s method of storing spatial data is not directly supported by a GIS software platform, GeoDecisions had to develop a workaround in the application’s backend that simultaneously displays map layers according to user preference, eliminating the need to distinguish between technically disparate datasets of points, lines, or polygons. System performance was a major obstacle for PennDOT and GeoDecisions to address in a system as large as this, with so much geospatial data and analysis. Load testing and large unit testing / system testing efforts were conducted across the Commonwealth to ensure that proper speed and responsiveness were achieved. Another design challenge was deciding how to represent the enormous volume of data via a map and to enable PennDOT to make better business decisions. Many hours were spent tuning the database and partitioning the large maintenance datasets from SAP in Oracle® to categorize and store the data efficiently. A large layer and map catalog was created as metadata to provide a streamlined way to display and locate the data a user wants. More than 2,000 map layers we defined and more than 25 template maps were developed to guide users to the data they require.

5. What Makes Maintenance-IQ Exemplary?

Maintenance-IQ provides a blueprint for higher-level GIS functionality not seen before in the transportation space. PennDOT and GeoDecisions deployed Maintenance-IQ as an enterprise GIS solution to help PennDOT users mine data, process information quickly, and better collaborate. In the past, PennDOT’s approach to maintenance planning and asset management was time consuming and involved a GIS operator with specialized software to develop multiple map versions. PennDOT’s pavement management process alone required almost two weeks for an operator to create 20 different map versions representing a one-time snapshot. Another original design concept featured in Maintenance-IQ is a central database to store user specific-views of robust data and maps that can be rapidly displayed, shared, and edited for other users.
Visualization Hub. A single-source GIS, Maintenance-IQ is revolutionizing how PennDOT plans and schedules maintenance activities. Maintenance staff can access the intranet-based application to create, load, share, clip, print, or validate current data without the assistance of a GIS professional. Maintenance-IQ enables PennDOT personnel to load existing maps or generate custom ones from an intuitive, self-service, and menu-driven toolset. Because the system pulls in dynamic data sets, users have access to the latest and greatest data, rather than a static map that is quickly outdated. Through plug-ins, users drag and drop location-based spreadsheets and information for immediate visualization, while simultaneously displaying project-related electronic documents or VideoLogs that show PennDOT’s automated collection of pavement conditions and roadway imagery. With an easy-to-use interface, Maintenance-IQ helps staff reduce mobilization costs, increase daily production, scope improvement needs, efficiently sequence assignments, and better collaborate with regional maintenance crews throughout the state.

Powerful Location Intelligence. By making data more accessible, Maintenance-IQ redefines the way PennDOT personnel improve project quality, facilitate vendor coordination, and reduce equipment repair and replacement costs. For example, as PennDOT’s primary data warehouse to inventory state-owned highway features, conditions, and characteristics, the Roadway Management System (RMS) is a complex mainframe difficult for even an experienced user to navigate. With Maintenance-IQ, the novice RMS user can easily obtain information necessary for funding, business planning, project design, and maintenance programming decisions. Improved access to RMS data helps PennDOT managers to balance workload, maximize efficiency, and facilitate district-based maintenance crew collaboration.
**Unbridled Efficiency.** Consistent with PennDOT’s enterprise technology approach, Maintenance-IQ is at the core of the agency’s new set of geospatial tools, widgets, data, and mapping services focused on reusability, flexibility, and convenience. The application enables users to request any dataset, then filter, display, and share information as desired. For example, Maintenance-IQ’s self-service environment, combined with the PennDOT Extract, Translate, and Load (PETL) plug-in, allows operators to display spreadsheets as layers that can be filtered with Google-like functionality. Another original design concept, Maintenance-IQ features a central database to store user-specific views of robust data and maps that can be displayed, shared, and edited for other users.

**Business Savvy.** Maintenance-IQ technology can be reused by maintenance and non-maintenance PennDOT groups with GIS business needs, providing PennDOT with a smart, repeatable process and enhancing access to actionable data. Applied to different PennDOT web applications, GeoDecisions’ shared common code reduces PennDOT’s future re-coding efforts and avoids re-inventing the wheel to meet mapping goals. For example, the agency’s new Traffic Data System, also developed by GeoDecisions, uses parts of the Maintenance-IQ common architecture to help verify more than 300 million records per month statewide.

**GIS Integration.** Maintenance-IQ transforms how PennDOT handles complex operations through the power of GIS. When creating the application, GeoDecisions accounted for data staging processes, owner coordination to build and consume data services, and the need to easily save and share maps between users by building Maintenance-IQ on top of the Oracle® and Esri® ArcGIS software platforms. The project required managing more
than 100 datasets from more than 20 separate systems, including external data from other state agencies, into nightly refresh cycles while developing mapping templates to guide user workflows and queries.

**Accessibility.** Considering PennDOT’s computer-cluster IT architecture, GeoDecisions implemented back-up procedures to ensure uninterrupted service of the agency’s IT systems during Maintenance-IQ development. GeoDecisions also designed Maintenance-IQ to feature active directory control for security, login, and user profiles through PennDOT’s intranet. The application integrates a mobile application component that provides photos taken in the field (using an iPhone or iPad) to document highway and bridge deficiencies or repair needs.

**Clear Picture.** Advanced geospatial processes are integrated into Maintenance-IQ, providing application users with a hassle-free experience. Because PennDOT’s method of storing spatial data is not directly supported by a GIS software platform, GeoDecisions developed a workaround in the application’s backend that simultaneously displays map layers according to user preference, eliminating the need to distinguish between technically disparate datasets of points, lines, or polygons. This process allows users to simply create asset visualizations, such as line and point features associated with bridges, while connecting Maintenance-IQ to a powerful enterprise GIS behind the scenes.

**Fast Find.** In “big-data” agencies such as PennDOT, where the data is owned and maintained throughout dozens of departments or bureaus, it can be difficult for the average staff member to find information. To solve this challenge, Maintenance-IQ integrates with PennDOT’s complex data structure and software platform, while simultaneously providing the end-user with an intuitive interface. The application’s self-service environment features a menu-driven set of customized map layers and specified variables while using consistent maintenance activity naming conventions to help find and organize information. Map layers include data attributes and filtering capability, such as traffic or roughness thresholds and posted road, bridge, or weight restrictions. Users also can quickly display either a VideoLog or Google Street View image of a selected map point.

**On-The-Fly Mapping.** An important PennDOT requirement, Maintenance-IQ users can work with location-based documents and spreadsheets seamlessly through GeoDecisions-developed plug-ins. Interactive displays illustrate how more than 10 business and legacy IT systems were integrated through Maintenance-IQ to provide dynamic data and informed decision-making. For example, users can compare data on planned and completed projects with asset and condition information, including highway and bridge inventory or environmental areas, to correct out-of-cycle maintenance activities.
The application synthesizes maintenance-related data from PennDOT information management systems dealing with:

- Bridge maintenance
- Contracts and document management
- Environmental protection
- Google street view and VideoLogs
- Highway performance monitoring
- Multimodal project management
- Pavement management
- Political boundaries
- Roadway management
- Spreadsheet visualization
- Strategic environmental management programs
Section D. Implementation

1. Project Phases

The phases included in the initial development and deployment of the Maintenance-IQ application were as follows:

**Phase 1: Project Initiation**

The purpose of Project Initiation was to establish and gain consensus from PennDOT on our approach to project execution. The first task was to complete an initial Work Plan that provides a copy of the final scope of work to be executed, a project schedule, initial project risks, project communication and reporting protocols, points of contact, and the project change management approach.

**Phase 2: Requirements Analysis**

Detailed requirements discussions were warranted to reduce risk and make certain of proper understanding of PennDOT’s needs. This understanding was critical to the success of the remainder of the project. The requirements drove the design and development activities and served as the basis for developing the testing criteria and subsequent test scripts required to verify the accuracy of the new Maintenance-IQ application. GeoDecisions compiled a brief Requirements Document deliverable, which underwent internal quality review prior to delivery to the PennDOT Project Manager.

**Phase 3: System Design**

The team then proceeded with detailed system design efforts. The Design Document provided detail on the technical design of the specified components of the new Maintenance-IQ application, including database design. This phase also included mock-
ups of the enhanced user interfaces to be provided to end-users based on the requirements.

**Phase 4: Application Development**

Based on the approved Design Document for Maintenance-IQ, the GeoDecisions team began development, conducted testing, and held preliminary client walkthroughs of the new application. The GeoDecisions team started by first developing a detailed work breakdown structure for this effort and established the development environment. Our team worked to make certain that the technical infrastructure required to distribute Esri® mapping services was properly established. Basic connectivity tests were performed to make certain that this Esri® link was established and available.

With this connectivity established, the team continued on the development tasks. The physical data model was finalized and deployed to the development environment. The development team then proceeded with constructing the new application. A preliminary walkthrough was held, and served as an opportunity for key members of PennDOT’s team to become familiar with the new Maintenance-IQ functionality prior to production deployment and user acceptance testing (UAT).

Our team then developed the test scripts and plan for the User/System Acceptance Testing activities scheduled during the implementation and deployment tasks. The test plan defined dates for the various testing activities during the course of the implementation and defined the conceptual approach to testing, defect tracking, and resolution reporting. The test scripts defined workflows, developed collaboratively by PennDOT and GeoDecisions, which walked users through a series of logical activities and verified that the output of each task is validated against an acceptable result. The test plan/scripts document underwent internal quality review prior to delivery to the PennDOT Project Manager.

**Phase 5: Implementation and Deployment**

The next step involved moving the new application to PennDOT’s staging environment. Concurrent with the installation of the application into the staging environment, GeoDecisions prepared “About” notes to provide additional user guidance.

With the new Maintenance-IQ application installed in the staging environment, PennDOT was invited to have up to eight staff members participate in UAT training for a period of two hours. These individuals were granted access to the staging environment to complete the UAT training and preliminary UAT. During the UAT training, GeoDecisions walked the PennDOT staff through the new application and the predefined testing scripts. This step helped set expectations in both teams, and provided initial training to a core set of PennDOT UAT participants.

Formal UAT proceeded for a period of ten business days, during which PennDOT executed the testing scripts, identified defects in the functionality, and formally recorded the user steps required to replicate the defect. Once defects were resolved, the new application was propagated to the stage environment for final review by PennDOT prior to product deployment. This final UAT lasted three days.

Next, the team proceeded with the production deployment. Once deployment was scheduled, GeoDecisions prepared the deployment packages and supporting
documentation. On conclusion of the initial deployment, GeoDecisions conducted internal systems acceptance testing according to the test plan and scripts to make certain that the new application was functioning properly. PennDOT staff members then proceeded with validations in the production environment.

At this point, a member of the GeoDecisions team with comprehensive knowledge of the new Maintenance-IQ application went onsite at PennDOT to provide a two-hour end-user training session to the staff members who will use the system.

**PHASE 6: POST IMPLEMENTATION MAINTENANCE**

During this maintenance period, services from GeoDecisions will include:

- Repairing break fix maintenance issues that arise and are formally reported by PennDOT
- Repairing minor bugs and fixes of deployed functionality
- Developing/adding minor enhancements (e.g., new report, new map layer, etc.)
- Providing planned/scheduled knowledge transfer regarding the maintenance of the Maintenance-IQ application to designated PennDOT staff

### 2. Modifications to the Original System Design

Following the initial deployment of Maintenance-IQ, the team has deployed several subsequent releases to provide additional functionality based on end-user feedback.

Since initial implementation, the following functionality has been added to the application:

- Buffer Analysis Tool
- Integration with additional external systems, such as pavement surface history, right-of-way data, and PennDOT’s electronic document management system
- Enhanced printing functionality to support high-quality large-scale plots
- Integration with PennDOT’s GeoSnap mobile application to display field photos within the Maintenance-IQ application
- Addition of several process-specific canned maps to monitor out-of-cycle roadways and maintain the five-year surface improvement plan
- Enhanced ability to share maps across large groups

PennDOT collaborates with GeoDecisions through the Maintenance-IQ Work Group. The work group is made up of power users across the Commonwealth and from different bureaus within PennDOT. This group works to prioritize future enhancements and functionality that will be added to the application.
Section E. Organizational Impacts

1. User Community

PennDOT’s Bureau of Maintenance and Operations staff members use Maintenance-IQ to improve statewide maintenance planning and coordination and help keep improvement projects on-cycle. Beneficiaries of the Maintenance-IQ system are Commonwealth of Pennsylvania Transportation Stakeholders, including:

- Central Office staff across several PennDOT bureaus, including the Bureau of Maintenance and Operations, the Center for Program Development and Management, and the Bureau of Planning and Research
- Engineering District staff, including Roadway Management Coordinators, Maintenance Foremen, District Engineers, and Pavement and Asset Managers
- County staff
- MPO/RPO planning partners
- Contractors and consultants

The monthly user base of the system is more than 300 users.
2. Improving Decisions/Operations/Services throughout the Enterprise

GeoDecisions deployed Maintenance-IQ as an enterprise GIS solution. Through an easy-to-navigate GeoDecisions interface design, the application enables PennDOT maintenance staff to visualize, analyze, and map planned and completed improvement projects from a central intranet location. They can then better understand how this information relates to transportation infrastructure assets and engineering conditions.

Using Maintenance-IQ, PennDOT personnel make more informed decisions that translate to better asset and infrastructure management and result in heightened transportation safety. A more efficient communication tool, the application expands infrastructure issue awareness while advancing geospatial excellence to PennDOT’s Bureau of Planning and Research and Innovations Office. Maintenance-IQ also enables PennDOT county and district users to deliver data and maps to legislators and outside stakeholders without depending on a GIS analyst.

Because PennDOT maintenance staff can better detect highway deficiencies, determine roadway treatments, plan operations, and monitor production, Maintenance-IQ will save $ millions in mobilization and labor investments. Smoother highways result in reduced vehicle wear and tear and less pressure to increase fees and taxes that fund PennDOT. Application efficiencies help PennDOT lessen traffic congestion,
promote enjoyable commutes, lower vehicle carbon emissions, and support enhanced environmental compliance.

3. Impacts of the System

**QUANTITATIVE IMPACTS**

- Staff members have the ability to identify and coordinate regional maintenance collaboration opportunities throughout the Commonwealth, reducing mobilization costs, increasing daily production, better scoping maintenance needs, and sequencing work assignments.

- By eliminating out-of-sequence rework, such as repaving a road before replacing underground pipes, Maintenance-IQ increases PennDOT’s operational efficiency – saving time and resources.

- Through making data more accessible, Maintenance-IQ helps PennDOT personnel improve project quality, increase productivity, facilitate vendor coordination, and reduce equipment repair and replacement costs.

- PennDOT’s new Traffic Data System, also developed by GeoDecisions, uses parts of the Maintenance-IQ common architecture to help verify more than 300 million records per month statewide. This common architecture leverages previous investments to support new projects, thus saving resources.

**QUALITATIVE IMPACTS**

- Maintenance-IQ is at the core of the agency’s new set of geospatial tools, widgets, data, and mapping services focused on reusability, flexibility, and convenience.

- Maintenance staff can access the web-based application to create, load, share, clip, print, or validate current data without the assistance of a GIS professional.

- Maintenance-IQ also enables PennDOT personnel to load existing maps or generate custom maps from an intuitive, self-service, and menu-driven toolset.

- Based on a framework of Esri® GIS technology consistent with PennDOT’s upgrade initiatives, Maintenance-IQ enhances PennDOT staff’s ability to access actionable data.

- Maintenance-IQ provides PennDOT with a smart, repeatable business process. With “PennBOTs,” GeoDecisions-developed plug-and-play application widgets that serve as shared common code, Maintenance-IQ functionality is reused by non-maintenance PennDOT groups with GIS business needs.

- Advanced geospatial processes are hidden behind the scenes in Maintenance-IQ, providing application users with a hassle-free experience.

- In “big-data” agencies such as PennDOT, where the data is owned and maintained throughout numerous agencies or bureaus, it can be difficult for the average staff member to find information. To address this challenge, GeoDecisions’ Maintenance-IQ solution integrates with PennDOT’s complex data structure and software platform while simultaneously providing the end-user with an intuitive interface.
• Easy-to-use plug-ins enable users to drag and drop location-based spreadsheets and information for immediate visualization, while simultaneously displaying project-related electronic documents or VideoLogs displaying PennDOT’s automated collection of pavement conditions and roadway imagery.

4. Increasing Productivity

The initial goals for the system that were identified during the requirements phase of the project have all been realized since Maintenance-IQ has gone live.

Using Maintenance-IQ, PennDOT personnel make more informed decisions, translating to better asset and infrastructure management, and resulting in heightened transportation safety. Replacing underground pipes prior to paving a road surface improves public perception, saves drive time, and eliminates PennDOT maintenance crew re-work. Maintenance-IQ also enables PennDOT county and district users to deliver data and maps to legislators and outside stakeholders without waiting for a GIS analyst.

After a little training, PennDOT staff can use Maintenance-IQ to complete tasks in minutes that once took several people weeks to accomplish.

5. Other Benefits

Other benefits realized from the use of the Maintenance-IQ application include:

• Providing significant reduction of non-productive travel time/costs (mobilization/fuel costs)

• Helping counties create cycle maintenance programs

• Decreasing on-demand maintenance (e.g., potholes, crack sealing)

• Facilitating significant data clean up in source data systems because the application allows users to visualize data and quickly identify outliers and other issues

• Identifying regionalization opportunities to leverage resources across county lines

• Providing maintenance foreman with data refreshed data to track crews progress

6. Improving How Business is Conducted

By making data more accessible, Maintenance-IQ helps PennDOT personnel improve project quality, increase productivity, facilitate vendor coordination, and reduce equipment repair and replacement costs. For example, the Roadway Management System (RMS), PennDOT’s primary data warehouse for inventorying state-owned highway features, conditions, and characteristics, is a robust mainframe difficult for an experienced user to navigate and extract maintenance-related information. With Maintenance-IQ, novice users can easily access RMS information necessary for funding,
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business planning, project design, and maintenance programming decisions. Thanks to this level of intelligence garnered through Maintenance-IQ when using RMS, PennDOT District 3-0 decided to transition specialized crews such as milling, surface treatment, and paving from county-based to regional locations. Projects assigned through regional crews not only help PennDOT management balance workload and maximize efficiency, but facilitate additional coordination opportunities with district-based maintenance crews.

PennDOT crews access the Internet-based application to create, load, share, clip, print, or validate current data without asking a GIS professional for assistance. This frees up PennDOT and District GIS analysts time to focus on more robust spatial analysis work instead of supporting daily map making needs. Maintenance-IQ empowers users to load existing maps or generate custom maps from an intuitive, self-service, and menu-driven toolset. Examples of business case maps that users can load and customize are provided as screenshots below:

![5 Year Surface Improvement Plan](image)

Managers can use the GIS system map to visualize the 5 Year Surface Improvement Plan (paving) funded by maintenance and capital appropriations:

- Improves planning for prep work and preservation activities
- Assists in identifying coordination opportunities (regionalization)
Pipe replacement is a common maintenance activity. Maintenance-IQ enables maintenance managers to quickly and easily identify recommended pipe replacements by type (e.g., cross pipe, parallel pipe, etc.), size, and material (e.g., metal, concrete, etc.).

Managers can use the GIS system map to visualize the prep work activities “planned” after surface improvement projects (paving). This is a proactive map that helps to eliminate out-of-sequence rework (e.g., prep-type activities performed soon after a surface improvement).
The GIS system map above supports getting preventative maintenance (e.g., crack sealing, shoulder cutting, seal coat) activities “on-cycle,” in turn decreasing on-demand maintenance needs and efforts.

The GIS map above demonstrates how Maintenance-IQ was used to develop a “cycle-sectional” maintenance crack sealing program (four-year cycle). By working within geographic zones; we further optimize the efficiency of the operation by reducing mobilization costs via travel time.
The map above was customized by District 3 to compare data from the Road Condition and 511 data/sites and how they relate to the pipe inventory and floodplain data to show relationships and devise plans of attack for repairs.

Template maps show where certain types of roads are beyond their pavement life and need to be replaced completely.
Quick and easy buffers identify possible wetland impacts and runoff possibilities.

Users can view and validate material mixes being used throughout a district related to level of service.
PennDOT’s mobile application team developed an internal mobile app called “GeoSnap” that enables highway foreman and maintenance managers to take photos from their iPhone and/or iPad and upload them into Maintenance-IQ. Before/after photos document flood-related damages for potential reimbursement from PEMA and FEMA.
Section F. System Resources

1. Hardware Components
   - Web Servers (Production, Stage, and Development)
     - Microsoft Server 2012
     - IIS 7.5
     - .NET Framework 4.5
   - Database Servers (Production, Stage, and Development)
     - Microsoft Server 2012
     - Oracle® RAC clustered/high-availability database servers to house the GIS data
     - Database links to SAP and DB2 for legacy/mainframe data to feed the GIS data
     - Network SAN configuration for large storage needs
   - GIS Servers
     - Windows 2012
     - Esri® ArcGIS Enterprise 10.2.2
   - VideoLog Servers
     - Windows 2012
     - Network SAN configuration for large storage needs
- Holds up to 14 years of VideoLog images for the state roadways

- Mobile Devices
  - Apple iPads and Apple iPhones (version 6 and higher); used for the GeoSnap native iOS application developed in-house by PennDOT for field crews to take pictures of maintenance needs, flooding, etc.

2. Software Components

Application Development
- Microsoft Visual Studio 2015 VB/ASP.NET
- WebAPI 2 – C#.NET
- AngularJS 1.3
- Bootstrap
- TypeScript
- NodeJS
- Python
- Crystal Reports 2008

Database
- Oracle/Oracle Spatial 11gR2 with spatial partitioning and Oracle RAC
- DB2
- SAP

GIS/Mapping
- Esri ArcGIS Server 10.2.2
- Esri ArcGIS Online
- Esri ArcGIS API for JavaScript 3.x
- Custom Developed Esri GeoProcessing Python Services for Spatial Analytics and Large Scale Plotting

3. System Data

Database
- Oracle®/Oracle Spatial
- Nearly 14 million records can be displayed within the Maintenance-IQ application
- More than 2,100 layers are provided to users (not counting the ones they can create themselves)
- More than 26 administrative (canned) maps are available to users
- Oracle Spatial is used to compare maintenance data against planning data to find gaps and overlaps
- Cycle maintenance datasets are created to identify areas where maintenance is due based on cycle parameters
- Nightly jobs refresh the data from numerous sources, including PennDOT’s SAP system (real-time maintenance data), ITS traffic cameras, CDART (crash/safety), RCRS (road closures), Winter Maintenance, TDS (traffic), VideoLog, DEP environmental data, and RMS

*Maintenance-IQ leverages Oracle® and Esri® ArcGIS software platforms.*
4. Staff Resources

Both GeoDecisions and PennDOT have collaborated to form a team of people that created and now maintain this system. The GeoDecisions team includes a Project Manager, a Technical Architect, a Senior Developer, a Developer, a Database Administrator, and a GIS Analyst. The PennDOT team consists of the System Owner, the Application Project Manager, and the Maintenance-IQ work group. The Maintenance-IQ work group is made up of eight super users from across the state. They meet monthly to plan for regular application releases, and annually to conduct visioning for the system as a whole.

5. Use of Resources

To help guarantee satisfaction and spread the word, GeoDecisions worked with PennDOT to complete 36 sessions spanning 11 weeks of onsite Maintenance-IQ training throughout PennDOT counties and districts. Participants included PennDOT county managers, county maintenance assistant managers, roadway program coordinators and technicians, district maintenance managers and program coordinators, and central office quality assurance staff.

The Technical Architect of the Maintenance-IQ system leads a training in PennDOT engineering district.