District Highway Maintenance Research On-Call (ROC) – Task#3 ODOT Maintenance Workflow

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16. Abstract

ODOT funded this study to investigate maintenance scheduling practices in the US and search for potential software systems that are capable of alleviating the challenges of maintenance scheduling. The project conducted a national scan and extensive agency outreach to evaluate existing approaches. It further completed interviews with ODOT staff and developed a set of criteria for a maintenance scheduling system. An initial list of potential vendors was narrowed down to three that appeared to meet the detailed requirements developed through this research, and software demonstrations were scheduled with all three. Across vendors, the software was distributed as a software-as-a-service, resulting in an annual price which may depend on the number of users. Some vendors have existing licensing agreements with ODOT, which may carry over for this use case. Further studies should be conducted to assess the costs and savings, including of workforce hours, of adopting the solution identified in this report. Additionally, consideration for developing an in-house solution should be assessed.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

There are wide variations between how different ODOT Districts and counties plan and record their maintenance activities. Many rely on manual methods, such as using calendars and lists on whiteboards or rearranging paper post-it notes, while others use digital methods, inputting activities into Excel workbooks. Despite these differences, ODOT maintenance staff across Districts share common needs: to reprioritize activities to address reactive and emergency services; to coordinate equipment and staff during the appropriate seasons to conduct the work; to record the work completed each year. ODOT funded this study to investigate maintenance scheduling practices in the U.S. and to search for potential automated systems (in software) that can address challenges they face in this area.

To evaluate needs and opportunities, the research team conducted internal meetings and interviews to understand ODOT's current practice. The research team also conducted a document scan of literature from the Federal Highway Administration, Transportation Research Board, and American Association of State Highway and Transportation Officials to assess the state of practice in the U.S. Additionally, a questionnaire was sent out to State DOT representatives to learn their perspectives and practices on maintenance planning and scheduling. Interviews were scheduled with five of these State DOTs.

A search for potential off-the-shelf automated systems determined that software capable of alleviating challenges related to maintenance scheduling were available. Desired functionalities based on ODOT's needs and requirements included the following criteria:

- Can schedule daily work plans
- Tracks priorities and ensure lower-priority items are not forgotten
- Has mobile capabilities
- Sends reminder notifications if priorities are not addressed
- Sends notifications to managers when incidents are added
- Integrates with and pulls work item information from the Collector App
- Ideally be able to interface with the Enterprise Information Management System (EIMS)
- Sorts work items by priority
- Has the ability to take pictures and store the GPS coordinates on a map

Based on the assessment of the document scan and State DOT agency outreach, the team identified potential vendors with off-the-shelf solutions for maintenance planning and scheduling. After comparing these candidate software solutions against the identified needs, the team scheduled software demos for three vendors to understand product functionalities and product fit.

When evaluating vendors against these criteria, Esri was identified as a comprehensive solution. Smartsheet was another potential solution that would need to be configured but could meet all the criteria. The existing version of Agile Assets EIMS, which ODOT currently

uses, meets only some of the criteria, however it could meet more in the future depending on what additional features are enabled by an ongoing update. It may be the case that, once fully updated, Agile Assets EIMS could interface with other vendor solutions such as Esri or Smartsheet, although this would have to be explored further with the Agile Assets team. Across all vendors, software was distributed as a software-as-a-service, resulting in an annual price to run the product and/or a one-time fee for professional services. The annual price was generally dependent on the number of active employees using the software.

The project concluded that potential scheduling systems that met ODOT needs and requirements to address maintenance scheduling challenges are available as off-the-shelf solutions, with the ability for customization to ODOT needs. Based on existing software that ODOT already uses, Esri would be the preferred tool as it currently is being used to collect and store workplan items. It would allow for ODOT staff to continue to use existing forms and processes, which would allow for ease of transition. If the update of Agile Assets includes the ability to collect workplan items, it may also be an option for further consideration. In addition, ODOT has existing contracting mechanisms with both Esri and Agile Assets.

PROJECT BACKGROUND

There are wide variations between how different ODOT Districts and counties plan and record their maintenance activities. Many rely on manual methods, such as using calendars and lists on whiteboards or rearranging paper post-it notes, while others use digital methods, inputting activities into Excel workbooks. Despite these differences, ODOT maintenance staff across Districts share common needs: to reprioritize activities to address reactive and emergency services; to coordinate equipment and staff during the appropriate seasons to conduct the work; to record the work completed each year.

This study investigates existing maintenance scheduling practices in the U.S. and across Ohio for a potential software solution that would support all ODOT maintenance staff. The study tasks included:

- Documenting current ODOT practices and identifying needs and requirements;
- Conducting literature review and agency outreach to assess current maintenance scheduling practices; and
- Identifying vendors with software products that could assist with maintenance scheduling and planning on-screen demonstrations with three of these vendors.

APPROACH

The project team conducted internal interviews with ODOT staff to gain a baseline understanding of the unmet needs in current maintenance scheduling practices. Although ODOT staff used different practices and tools, the project team captured the general shape of maintenance workflow in a flowchart. Concurrently, the team performed a scan of documents to assess the current national practice of maintenance scheduling in the U.S. and published a questionnaire to send out to State DOT representatives and committees to gain perspectives on maintenance scheduling. This survey was distributed through the AASHTO Committee on Maintenance.

From these efforts, the research team identified potential off-the-shelf software systems and noted observations on the different maintenance schedule practices and tools across agencies. The team then compared the vendors used by other State DOTs against ODOT'S identified unmet needs and ODOT's workflow flowchart to determine product fit. When appropriate, the research team scheduled demos for the ODOT team to see the software in a relevant use case and assess product functionalities.

The high-level approach is summarized in Figure 1. Details for the approach taken each step are documented on the next page.

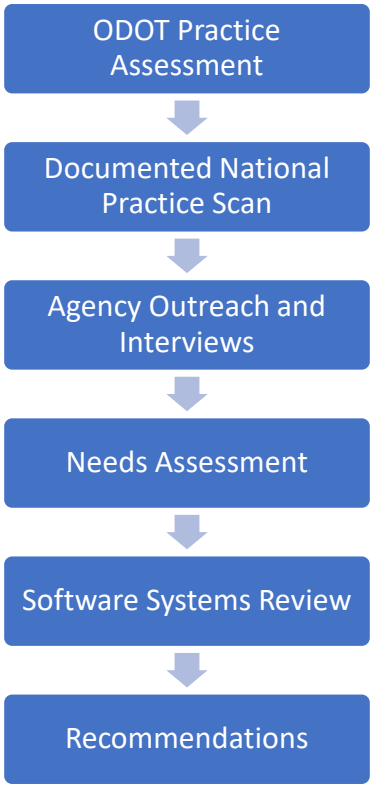


Figure 1 Flowchart of Project Approach

ODOT Practice Assessment

The research team reviewed ODOT practices and documented the current decision points maintenance staff encounter throughout workflow in a flowchart. This review unfolded as a series of virtual meetings with regional staff in ODOT Districts and counties. The following questions were prepared for guidance in conversations with ODOT to understand their current state of practice, needs, and requirements:

- What are your roles in maintenance work planning? Anyone else involved?
- Can you walk through your process of collecting, planning, and scheduling maintenance work items?
- What are the various sources you collect work items from (i.e., Inspection Reports, Citizen Complaints, Asset Management Systems, Roadway Improvement Programs, Crash Records)?
- What factors are considered for prioritizing maintenance activities?
- How often is the maintenance work plan updated?
- How do you accommodate non-planned activities into your planned program, such as responding to emergencies, weather events, and crashes?
- What software and/or tools do you use for maintenance planning?
- If you are using a software, what has been your experience with the software? What works well and what doesn't?

- If your practices have been improved recently, what software and/or tools did you use previously?
- What types of changes would you like to see implemented to allow you to work more effectively?
- Do you have a written policy or guidance on planning and programing maintenance activities? If so, please send a link.

ODOT staff explained their step-by-step process that their staff takes to schedule maintenance activities, including the use of the existing platform being used in many of the local ODOT offices. The ODOT staff also shared their needs for a maintenance scheduling system. Through these activities, the team summarized ODOT needs and requirements for a maintenance workflow scheduling system. This documentation served as the evaluation criteria for identifying available software systems in the following tasks.

Document Scan of National Practice

The project team reviewed available documents from national authorities and related organizations to learn their maintenance workflow scheduling and related software systems. The team searched for existing research, past projects, or documented best practices related to maintenance workflow planning, scheduling, applications, and software systems.

Agency Outreach and Interviews

Using findings from the national practice document scan and input from related AASHTO committee contacts, the project team and ODOT staff jointly identified five state agencies to interview about their experiences with maintenance workflow scheduling. The interviews were conducted virtually. Interviewees were asked to elaborate on their electronic systems and clarify their survey responses. The same questions used for the ODOT Practice Assessment were used for the research survey.

Needs Assessment

The team summarized key findings from prior subtasks, including the state of practice within Ohio, with a slide deck. The presentation offered a foundation for identifying potential gaps in practice and opportunities for investments and further research.

Software Systems Review

The project team conducted a review of potential software systems to identify candidates that could potentially meet ODOT's needs and requirements. The project team conducted both an online search with keywords, such as maintenance work planning and work order scheduling systems utilized by other state DOTs and other related industries, and explored additional software products offered by existing providers that ODOT already uses. For vendors of interest, online inquiries were submitted, or emails were delivered to engage in further conversation specific to functionalities, product fit, and a potential demo. After continued discussions with ODOT and assessing product fit with vendors, three virtual product

demonstrations were scheduled to allow the project team and ODOT staff to see the available system in use and ask any remaining questions. A functionality matrix was utilized to summarize the information discovered in this task and compare the systems identified through the conducted scan. This included notes on functionality, reporting capabilities, staff and event logging, and pricing structure.

Recommendations

The team compared information from the existing systems and available maintenance scheduling software systems against ODOT's needs and requirements. The team weighed the capabilities of available systems to meet ODOT's needs, focusing on feasibility of integration, prioritization of work items, compatibility with the existing Collector application, and data security. The team also discussed pursuing a customized solution for ODOT, but this option was deemed time-consuming and expensive.

Based on all the findings from prior tasks, the team developed general recommendations for the adoption of a potential software system to address challenges associated with maintenance scheduling. Recommendations provide an informed perspective on the benefits and drawbacks of implementing the available software systems.

ODOT PRACTICE ASSESSMENT

Three tools are used in tandem as part of ODOT's maintenance, scheduling, and work-tracking efforts. These include the Biweekly Inspection, the Collector app, and EIMS/day cards, which are each described in the following sections.

Biweekly Inspection

The Biweekly Inspection requires County-level staff, such as transportation managers (TMs) and transportation administrators (TAs), to monitor their roadway conditions and record any deficiencies, such as potholes or damaged signs, every other week. The Collector app is used to record deficiencies.

Collector App

The Collector app is an ODOT-sanctioned, Esri-based tool that utilizes ArcGIS Field Maps to track asset inspections and any associated work items related to items such as culverts, underdrains, guardrails, overhead sign structures. It holds the information recorded as part of the Biweekly process to document deficiencies on the roadway. Each deficiency is logged as a point with geographic coordinates and can have photos attached for reference. Various attributes associated to the deficiency may also be recorded in the Collector App, such as priority level and comments/notes. In addition, TMs and TAs can use this tool to identify the priority of each work need.

Upon returning from the field, ODOT staff can use the Collector app to review a web-based map and dashboard to show the maintenance needs within their jurisdiction. Both the map and

dashboard allow for some filtering capabilities based on work type and priority. In addition, this information can be exported to .CSV spreadsheets. Recorded deficiencies can help track open work items that need to be addressed.

EIMS/Day Cards

The EIMS tool is ODOT's work order management system created by Agile Assets. EIMS is part of the post-processing process of completed work and is used to keep track of completed work and cost items, which is required by ODOT's central office. From a workflow perspective, technicians would fill out their day card work sheet, as shown in Figure 2, to track which work items they completed that day. This is then submitted to the TAs and TMs, who review and process the information through the EIMS system. The current practice requires a manual process of entering data multiple times and may benefit automation. EIMS also has various functionalities that are not related to work planning, such as tracking equipment; however, the actual use of other functionalities may not be consistent across the state.

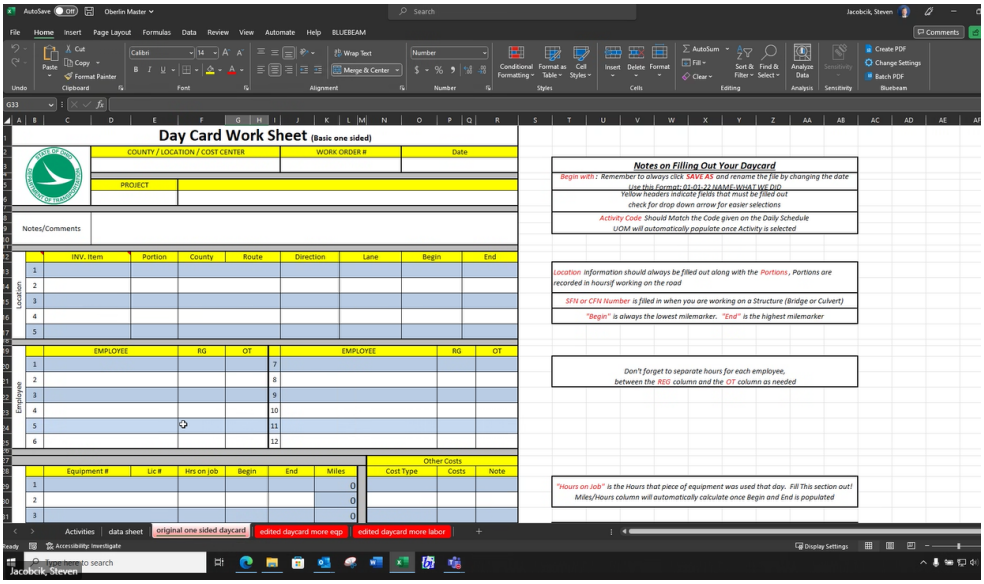


Figure 2 ODOT Day Card Work Sheet

ODOT Outreach

Concurrent to the external agency outreach and review of existing tools, similar efforts were taken to understand ODOT staff's approach to scheduling maintenance activities. First, an online survey was sent to ODOT maintenance staff. Following this, a series of interviews were conducted with representatives from each division. As mentioned, a survey was provided to all ODOT maintenance staff, including TMs, TAs, and Roadway Services Engineers, and had 46 participants, representing all Districts in Ohio. This survey was supplemented by four group interviews conducted with ODOT staff. Table 1 illustrates who was represented in each of the interviews.

Table 1 Internal Interviews

Interview ID	District Representation
1	1, 2, 7
2	3, 4, 12
3	5, 6, 11
4	8, 9, 10

The sections below provide key takeaways from the survey and interviews.

Frequency of Updating Workplans

As shown in the figure below, most respondents update their workplans daily. It is also apparent that TMs are generally updating workplans more frequently than TAs.

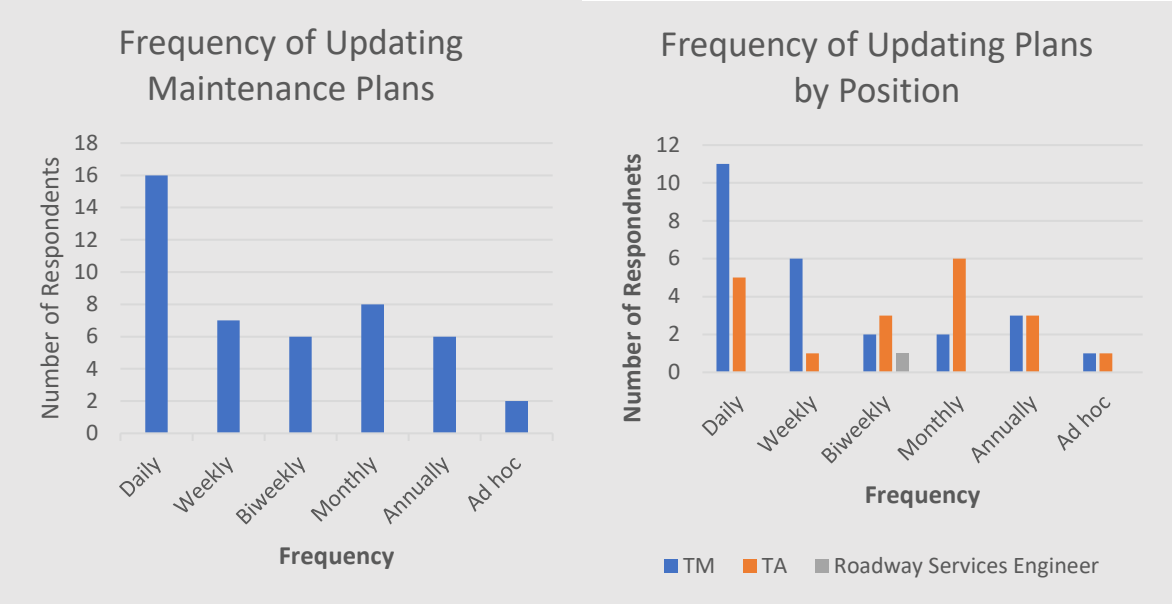
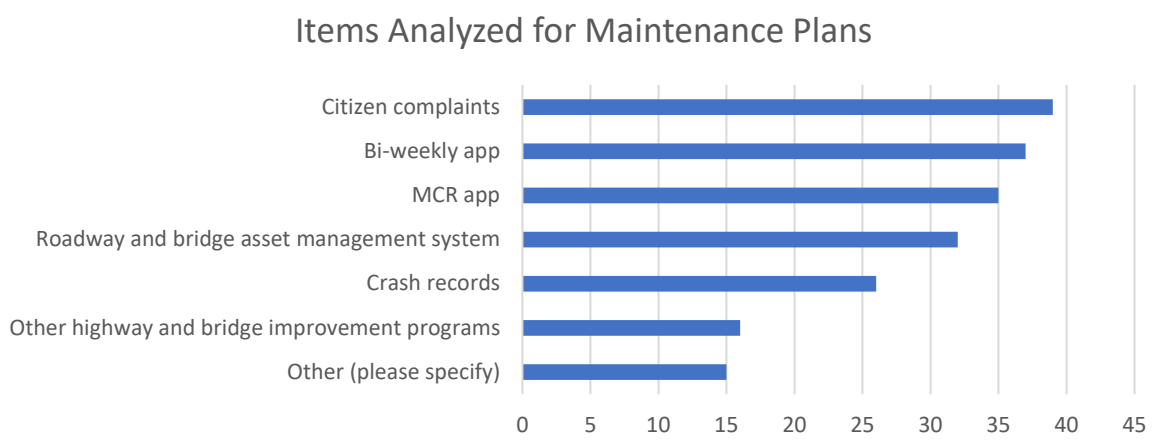


Figure 3 ODOT Frequency of Updating Workplans

Items Analyzed for Maintenance Plans

The survey provided the opportunity for staff to describe what items are analyzed in their maintenance plans. As shown in Figure 4, data comes from a variety of sources, including those that are ad hoc, i.e. citizen complaints, as well as programmatic items, such as the roadway and bridge asset management system.



*"Other" category includes paving schedules, culvert ratings/work order program, HTs documenting/ reporting deficiencies, upcoming capital programs, District Vegetation Program, EIMS SQL, and material history reports.

Figure 4 ODOT Items Analyzed for Maintenance Plans

Existing Methods for Planning Activities

The research team explored existing tools and processes currently used by ODOT for planning activities. The tools included Excel, the Biweekly app, the Collector app, EIMS, District Culvert & Bridge work order program, Culvert web app, ODOT intranet portal, and PCRs. As shown in Figure 5, Excel is the most used tool. Excel is also used for the "Yearly Plan," which consists of a data entry spreadsheet developed by central office. The aim of this spreadsheet is to create consistency in the annual plans submitted by each of the local regions. Through conversations with TMs, TAs, and Roadway Safety Engineers, many staff members personally create or use spreadsheets unique for their District. These are primarily used for daily, weekly, and monthly scheduling of maintenance activities.

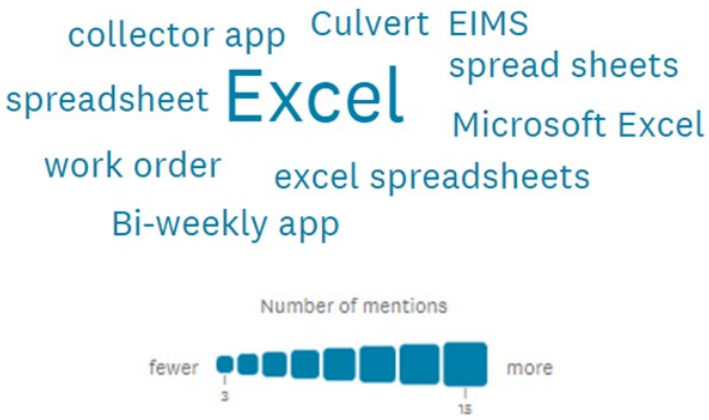


Figure 5 ODOT Existing Methods for Planning Activities

Reactive or Emergency Activities

The survey revealed that work plans are generally made without consideration for reactive or emergency activities. These types of unplanned events include high-priority safety concerns, such as weather events and crashes. In these cases, the items programmed in the workplan are delayed, rescheduled, and/or continued concurrently. In general, ODOT staff expressed the maintenance staff transition back to planned activities quickly, but often encounter challenges from weather impacts, borrowed/shared equipment availability, and scheduling conflicts for other planned work.

Satisfaction with Existing Methods

Outreach to ODOT staff also explored individual satisfaction for the existing tools and methods used for maintenance activities. Many individuals expressed confidence that current methods and tools kept their workplan up to date and reliable. Only two respondents reported as "dissatisfied" in any of the questions relating to satisfaction with existing methods. Both respondents currently use Excel spreadsheets.

In addition to their level of satisfaction, ODOT staff also provided ideas for recommendations, including the following:

- Tools that can link information together from different sources into one location/source would be useful for various staff positions and workplan activities.
- There is a great bit of time spent addressing the workplan when plans change due to reactive/unplanned activities. Tools that support staff reprioritizing activities would be useful.
- There is the general desire for more efficiency and integration of the existing methods and tools.

STATE OF PRACTICE REVIEW

This section elaborates on the findings from the review of ODOT's current state of practice, the national practice document scan, and the outreach efforts to state and local agencies. The section concludes by describing the needs and requirements illuminated by these findings.

National Practice Document Scan

The research team reviewed available documents regarding maintenance workflows from the Federal Highway Administration, Transportation Research Board, American Association of State Highway and Transportation Officials, and related organizations supporting public agencies. Combinations of keywords, including maintenance workflows, work planning, scheduling, work orders, maintenance management, applications, dashboards, and software systems, were used to search for documents.

Available documents did not point to specific vendors or software. Instead, they highlighted ongoing and completed work on modern approaches to identifying roadway conditions using

machine learning/artificial intelligence. Most of these methods study image-processing algorithms that utilize video from a smartphone to detect roadway conditions and defects. For example, an ongoing project for the Transportation Consortium of South-Central States is focused on developing a smartphone application to monitor pavement conditions and potholes/anomalies by attaching a smartphone to a vehicle[1]. If this project is completed and successful, the smartphone application can be beneficial across state DOTs and local municipalities to create time savings for pavement management practices. Additionally, another study conducted at The University of Texas at Tyler focused on developing a smartphone application for pavement maintenance that attaches a smartphone to a vehicle windshield and uses its sensors to detect roadway defects.[2]

In summary, most documents appear to be focused on the development of pavement management systems, specifically those using modern technology and smartphones to automate inspection processes. There were limited publications related to work planning or scheduling for maintenance work items, illustrating a potential gap in the documentation of existing practices across the U.S. related to maintenance scheduling practices.

Agency Outreach and Interviews

Concurrent with the document scan, the project team conducted outreach interviews with agencies to gather information on existing scheduling systems, practices, and experiences. In addition to other state DOT contacts through the AASHTO Committee on Maintenance, members from the "No Boundaries" pooled fund project, involving a group of state DOT maintenance and operations professionals, were identified as potential contacts for agency outreach based on their existing innovative practices or solutions.

Online interviews were conducted with five DOT agencies that were either already using an existing scheduling solution or in the process of developing a planning and scheduling system. The five agencies were:

- Pennsylvania Department of Transportation (PennDOT)
- Texas Department of Transportation (TxDOT)
- Colorado Department of Transportation (CDOT)
- Maine Department of Transportation (MaineDOT)
- Utah Department of Transportation (UDOT)

Each interview provided insight into that organization's structures, roles, and responsibilities; various planning and scheduling technologies; and contracting methods for developing/acquiring software to support their needs. Each interview is summarized below.

[1] SMARTP3M: Smart Pavement Monitoring, Management, and Maintenance. Momen, Mousa. 2022. https://trid.trb.org/View/1948652. Accessed May 30, 2023.
[2] Development of a Smartphone Application Serving Pavement Management Engineers. Stephens, Damien et al. 2022. https://trid.trb.org/View/1922969. Accessed May 30, 2023.

Pennsylvania Department of Transportation (PennDOT)

PennDOT staff described a decentralized structure, with maintenance responsibilities relegated to the District level. Managers and County managers oversee budgeting, scheduling, and assigning work to maintenance supervisors. The SAP platform is PennDOT's legacy system for material, fiscal, equipment, and staff. However, SAP does not provide a simplified approach to conflating the information in a manner to assist in maintenance planning and scheduling. Therefore, PennDOT hired Baker International to create software that assistant managers can use in resource balancing. The tool, which is in the process of being developed, will provide batch editing of activities and visual Gantt charts for scheduling. Because the software is not intended for field staff, it focuses on pre-planning activities and does not make accommodations for emergency activities. In these instances, it will require manual scheduling adjustments. PennDOT estimates that the tool is approximately six months away from completion and pilot testing. To date, PennDOT has spent approximately $250k on software development.

Takeaway: PennDOT has a many maintenance asset system that can be enhanced with customized software that merges vital data to assist in maintenance scheduling and budgeting. The customized software was developed in-house through existing open-ended contracts.

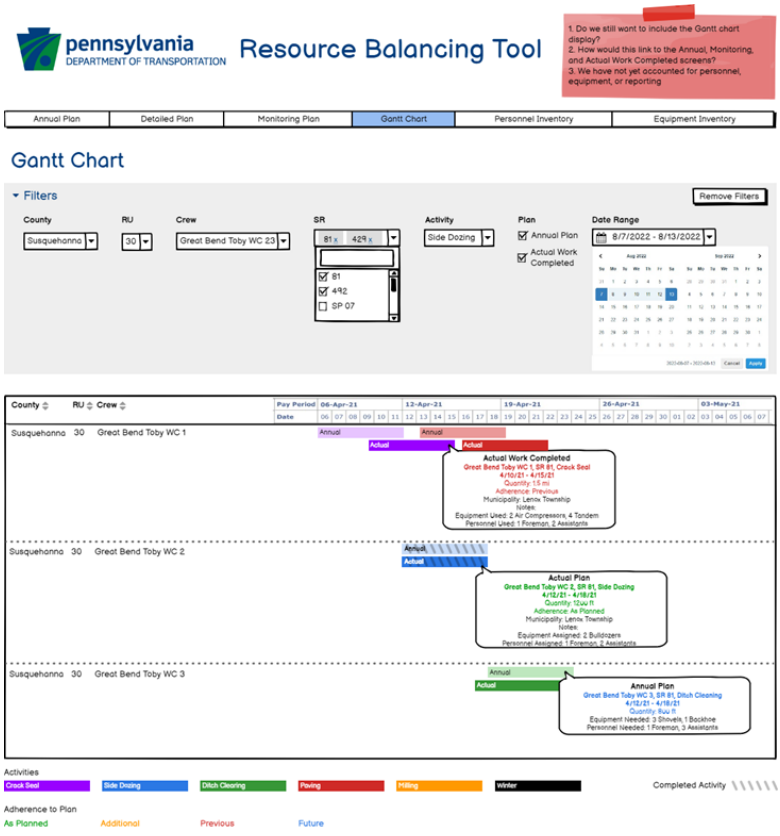


Figure 6 PennDOT Resource Balancing Tool

Texas Department of Transportation (TxDOT)

Like PennDOT, TxDOT has a traditional organizational structure, with maintenance responsibilities delegated at a District level. Planning, budgeting, and scheduling occur at a county-level maintenance "section" with managers. TxDOT develops maintenance scheduling at both the annual and four-year horizons. These individuals are supported by assistant managers to produce a four-year plan using Agile Assets Maintenance Management System (MMS). MMS is supported by a custom planning tool that focuses on coordinating TxDOT's 40 primary roadway activities in concert with its four-year plan. Parallel to the scheduling of activities, TxDOT also uses the People Soft for Human Resources software, which conflates with the planning system they created. At a high level, this allows for annual scheduling and budgets to be developed, including estimating the number of hours expected complete each work category. Although these tools are available for TxDOT staff, daily scheduling tends to be completed manually, as many see the existing tools and process to be too complex. Due to the challenges that staff have with these tools, these daily activities at the ground level are often completed manually, which results in inconsistency across the counties; some use whiteboards while others use Excel spreadsheets. To accomplish their internal goals, they are upgrading to the latest version of Agile Assets MMS, which should be completed in a few months.

Takeaway: Develop software that is not complex and usable by all staff. Agile Assets has other capabilities, but TxDOT is not using them.

Colorado Department of Transportation (CDOT)

Like PennDOT, CDOT is decentralized, with strong support for planning and budgeting from the central office. CDOT is divided into five regional offices and functional areas called "Maintenance Sections." Each section has a maintenance superintendent, who oversees the work tasks. To schedule the work tasks, CDOT uses an SAP application called "Work Manager." One challenge CDOT faced was providing appropriate equipment for their staff to log the work. Previously, laptops were given to all staff, but created organizational problems. They are now issuing iPhones to all staff, despite being unsatisfied with this approach. As a result, CDOT is going through the same outreach and evaluation as ODOT, and very interested in the UDOTS ATAM application.

Takeaway: When developing an application, thoroughly vet who and how it will be used in the field and what equipment they need.

Maine Department of Transportation (MaineDOT)

MaineDOT is divided into three maintenance regions and functions as a blend of centralized and decentralized maintenance. Bridge, traffic painting, and budgeting are managed in the central office, while roadway maintenance and preservation are delegated to the regions and their superintendents.

Because of the size, Maine collaborates with New Hampshire and Vermont on projects and initiatives for cost effectiveness. These three agencies collaborated on a maintenance planning

budgeting and scheduling solution called “Maintenance Activity Tracking System (MATS).” This tool was developed through an RFP process by Booze Allen for the last 15 years and cost $5 million. The MATs tool is comprised of a web-based activity training and assets management system. The activity tracking monitors daily reports, work requests, budgeting, payroll, and material management. It is the most comprehensive system created by any of the agencies interviewed. Because it is so robust, it requires full-time staff to maintain it and to teach and support the MaineDOT staff about its principles.

Takeaway: The three agencies invested an immense amount of time and money in developing a customized scheduling system; however, the software interface is relatively complex and requires a higher level of skill to manage it. It’s not for field personnel.

Utah Department of Transportation (UDOT)

UDOT has a decentralized organization, and the staff are typically non-unionized. It is divided into five regional offices, which are managed by District offices with work deployed out of maintenance stations, also referred to as “sheds.” UDOT migrated away from Agile Assets to their internal application called Operations Management System (OMS), but they found it limited to identifying locations of where work needed to be complete. For the last 15 years, UDOT has transitioned to using the application “Atom.” This application was contracted from an RFP and was awarded to a team that included Google for the visual mapping and interface; Mandli for lidar collection; Collins Engineering for the management of the civil engineering aspects; and SADA for the software management. To date, UDOT has spent about $2M on the application. Because the Atom software is web based, cell phones are issued to all maintenance staff. The software conflates human resources, materials, and equipment and results in useful visual mapping aspects and user-friendly interfaces. Representatives from UDOT recommend a gradual approach to building software for application and still consider theirs in development.

Takeaway: Developing software is a marathon, not a race. UDOT had the best interface and was very user friendly, which is necessary if all maintenance workers are expected to use it.

NEEDS ASSESSMENT

Through the engagement with ODOT and external maintenance staff, a list of needs was identified. Creating this list forged consensus on what features a future software tool would require. These requirements include:

- Can schedule daily work plans
    - This would allow managers to create, track, and change day-to-day work schedules.
- Has mobile capabilities
    - This would allow ODOT staff to use this tool while both with Wi-Fi network or offline.
- Sends reminder notifications if priorities are not addressed

    - This would support ODOT's goal to keep schedules on time.
- Sends notifications to managers when incidents are added
    - This would allow for managers to update the schedule to include repairs caused by incidents.
- Integrates with and pulls work item information from the Collector app
    - This would minimize the amount of data entry necessary to schedule work by taking already collected data from the Collector App.
- Be able to interface with EIMS
    - This would allow for information exchange and reduce the number of dual entries regarding completed work.
- Sorts work items by priority
    - This would help prioritize work items by tracking higher-priority items and ensuring lower-priority items are not forgotten.
- Has the ability to take pictures and store the GPS coordinates on a map.
    - This would help staff identify and track maintenance activities in the field.

These items served as evaluation criteria for potential software systems.

SOFTWARE SYSTEMS REVIEW

This section summarizes findings from the review of software systems, including the preliminary scan of systems, systems review, and pricing structure.

Preliminary Scan of Systems

A preliminary review of available maintenance scheduling systems used by other State DOT representatives and related industries identified the following potential automated systems that fit ODOT's needs and requirements:

- Agile Assets
- Fiix Software
- Smartsheet
- FMX
- Workflow Manager
- ArcGIS Workforce (Esri)

The project team conducted further research and due diligence through looking at information such as product functionalities, current clients in similar industries, customer reviews, documented presence online, and by conducting preliminary conversations with vendors that narrowed options based on product fit. Vendors with preexisting relationships with ODOT, such as Esri and AgileAssets, were prioritized if a solution could be implemented in parallel to existing systems. Through this initial vetting, further inquiries were submitted to ArcGIS Workforce (Esri), Smartsheet, and the existing Agile Assets program.

Automated Systems Review

Through evaluating vendors against the needs and requirements revealed through the state of practice review, Esri was identified as a preferred solution. Because ODOT already hosts its asset inspections on a feature service and uses ArcGIS products to record inspection details, Esri appears to provide an easier transition into meeting maintenance needs across the vendors and providing time savings on both implementation and staff training.

Smartsheet was another potential solution that could meet all criteria if configured appropriately to meet ODOT needs. Further conversations would be needed to determine what Smartsheet configuration would make sense for ODOT needs, which may result in more time necessary in the deployment process compared to other vendor, including Esri.

The existing version of Agile Assets EIMS meets some criteria. However, the functionalities of Agile Assets EIMS will need to be reevaluated after the ongoing two-year update is complete and relevant features are enabled. To make Agile Assets a feasible option for maintenance work planning, the update will need to include a way in which specific work items are stored and improvements in ease of functionality for staff. In addition, the work items would need to be visually displayed in real time for county level end users. If these upgrades are made, implementing a work-planning feature within the updated version of Agile Assets EIMS could offer time savings as the foundational software is already in-use at ODOT and staff have a baseline familiarity with the software. Additionally, there might be further benefits to tracking work plans and completed work within Agile Assets EIMS to reduce redundancies in data entry as currently required with day cards. However, it is worth noting that Agile Assets EIMS has not been used by ODOT at the county level for daily maintenance planning. In addition, Agile Assets EIMS does not currently house ODOT actual specific work items or schedule at the county level.

One difference to note across the vendors is the way they integrate and work with the data from the Collector app. Esri products can work off the same feature service, allowing for seamless multifunctional use of the same data in different products, such as ArcGIS Field Maps for the Collector app and ArcGIS Workforce or other products for assigning and completing work. Agile Assets has an existing partnership with Esri and can support integration between the two, which would need to be discussed after the Agile Assets update is complete. For Smartsheet, mapping capabilities are possible with an add-on, but the data for scheduling would be pulled in and viewed in a spreadsheet format.

The functionality matrix in Table 2 displays the functionalities of the three vendors we solicited demos from. It is noted that these results may differ from the initial screening based on vendor conversations.

Table 2: Functionality Matrix of Vendors

Functionality	Smartsheet	ArcGIS Workforce	Agile Asset EIMS
Can schedule daily work plans.	✓	✓	✓
Tracks priorities to ensure lower-priority items are not forgotten.	✓	✓	
Has mobile capabilities.	✓	✓	
Sends reminder notifications if items are overdue.	✓	✓	
Sends notifications to managers when incidents are added.	✓	✓	
Integrates with and pulls work item information from the Collector app.	✓*	✓*	
Interfaces with EIMS.	✓**	✓**	✓**
Sorts work items by priority.	✓	✓	
Has the ability to take pictures and store the GPS coordinates on a map.		✓	

* Smartsheet would pull the information in as a .csv while ArcGIS would work off the feature service that holds the information.
** The details of an interface between each vendor and Agile Assets will depend on further coordination and conversation with Agile Assets.

Pricing Structure

The identified potential automated systems that met ODOT criteria were software-as-a-service companies. Given the distribution model of these solutions, the pricing structure across vendors was similar with an annual price to run the product and/or a one-time fee for professional services. Because ODOT already carries Esri and Agile Assets products, ODOT has existing licensing structures in place for a suite of Esri products and EIMS. If add-ons are necessary for licensing for an additional product, further conversations with internal contacts would need to be held. For Smartsheet, licenses would be based on the number of users that need edit or create access to manipulate data and/or create schedules.

CONCLUSION AND RECOMMENDATIONS

This project identified several potential off-the-shelf software tools that meet ODOT needs and requirements and can alleviate maintenance scheduling challenges. The project team recommends further studies, including a cost-benefit analysis and continued conversations with vendors of interest, be conducted if ODOT wishes to adopt any one of these tools.

The project identified these criteria as minimum requirements for the systems:

- Can schedule daily work plans
- Tracks priorities and ensure lower-priority items are not forgotten
- Has mobile capabilities
- Sends reminder notifications if priorities are not addressed
- Sends notifications to managers when incidents are added
- Integrates with and pulls work item information from the Collector App
- Ideally be able to interface with EIMS
- Sorts work items by priority
- Has the ability to take pictures and store the GPS coordinates on a map.

Through evaluating vendors against these criteria, the research team identified three vendors for further discussion: Esri, Smartsheet, and Agile Assets. Software demos with ODOT staff and the project team were scheduled with Esri and Smartsheet. Given ODOT's existing adoption of Agile Assets and an update occurring in parallel with this project, an internal demo was scheduled instead of a vendor demo to walk through additional features available in the existing version of Agile Assets.

Of these vendors, Esri was identified as an off-the-shelf solution that could meet all the criteria and could provide the easiest transition, as ArcGIS Field Maps is used for collection of maintenance work items. Smartsheet was another potential solution that could meet the criteria, but it would require more work upfront to build an appropriate solution. The existing version of Agile Assets met some criteria, and its functionalities will depend on both the outcomes of the ongoing update and whether work planning-related features are enabled. Given ODOT's preexisting relationships with Esri and Agile Assets, working with either of these vendors for a maintenance work-planning solution are expected to offer benefits in time savings, training needs, staff familiarity, financial savings, and data integration options, if certain features that improve ease of use for county level end users and visual display of work items in real time are included in the update for Agile Assets.

Across all vendors, software was distributed as a software-as-a-service, resulting in an annual price to run the product and/or a one-time fee for professional services. For Smartsheet, the pricing will depend on the number of employees who would need access to edit or create within the software. For Esri and Agile Assets, pricing structures may differ based on existing established licensing agreements.

Another option could be developing an in-house solution, as demonstrated by MaineDOT. However, there are existing off-the-shelf software solutions already in use at ODOT that could provide better integration and time savings for ODOT staff.

The research concludes that adopting an off-the-shelf solution can be beneficial to ODOT to alleviate maintenance scheduling challenges. Working with Esri could provide benefits compared to working with other vendors based on established relationships and use cases of these vendors' products for maintenance at ODOT currently. Additional considerations to assess the cost and time savings of adopting a solution can be further evaluated internally prior to the adoption of a solution.