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Exploring Autonomous Maintenance Technologies (AMT) in INDOT Road Maintenance Activities: A Feasibility Study



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16. Abstract This project conducted a feasibility study of adopting autonomous maintenance technologies (AMTs) for Indiana Department of Transportation (INDOT) road maintenance activities. It surveyed state DOT representatives on AMT adoption, reviewed candidate AMT products and automation levels, and conducted a preacceptance survey to INDOT maintenance personnel. The market and technology reviews identified 51 AMTs across eight categories: snowplowing, mowing, crack sealing, pothole patching, traffic-control-device setup and retrieval, sweeping, culvert inspection, and roadway inspection and three automation types: full automation, partial automation, and remote operation. The INDOT survey showed cautious, technology-specific acceptance, with highest near-term potential for traffic control device setup, culvert inspection, and roadway inspection. Autonomous snowplowing had the lowest acceptance rate. The report recommends a phased adoption strategy that prioritizes low-exposure, inspection/data, and human-in-the-loop applications.			
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EXECUTIVE SUMMARY

Introduction

This project explores the feasibility of deploying autonomous maintenance technologies (AMTs) in Indiana Department of Transportation (INDOT) road maintenance activities. The study is motivated by the need to improve worker safety, maintain a growing and aging roadway network, and support maintenance productivity under workforce constraints.

The project considers eight AMT categories: autonomous snowplowing, autonomous pothole patching, autonomous crack sealing, automated traffic control device setup, autonomous mowing, autonomous roadway sweeping, autonomous culvert inspection, and automated roadway inspection.

Findings

The state department of transportation survey and follow-up information suggest that agencies are most comfortable with technologies that reduce worker exposure or improve productivity while preserving human oversight. Further analysis shows that AMTs are deployed unevenly across categories. Automated inspection and autonomous culvert inspection technologies have received more field deployment attention, while other

categories remain early-stage or have been implemented only in pilot studies.

The market analysis identifies 51 AMTs across the eight categories including three types of automation: full automation, partial automation and remote operation.

The INDOT preacceptance survey indicates cautious, technology-specific acceptance. Overall, 72.2% of respondents rate AMTs as very or somewhat important for future operations, but only 41.7% are very or somewhat supportive of adoption. The highest acceptance rates of AMTs are traffic control device setup and retrieval, culvert inspection, and roadway inspection. Autonomous snowplowing has the lowest acceptance pattern and the highest negative district-support rate.

Implementation

The recommended implementation strategy is staged and human-in-the-loop. INDOT could prioritize near-term deployment for automated traffic control device setup, autonomous or remotely operated culvert inspection, and automated roadway inspection. Crack sealing, pothole patching, mowing, and sweeping are promising but should be evaluated through targeted pilot studies that compare production rate, quality, operation time, and crew impacts against current practice. Across all AMT categories, implementations and/or pilot studies should include clear objectives, worker training, manual fallback procedures, quality control, and cost-benefit evaluation.

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1. INTRODUCTION

1.1 Problem Statement

Road maintenance activities are essential to the safe and efficient movement of people and goods. Well-maintained roadways extend pavement service life, reduce crash risk, and improve fuel efficiency (Louhghalam et al., 2017). Indiana Department of Transportation (INDOT) faces two major maintenance challenges: worker safety and the ability to maintain a growing, aging roadway network with a constrained workforce.

Worker exposure to live traffic environments remains a central concern in roadway maintenance activities. Work-zone crashes in Indiana accounted for 14 deaths and 650 injuries in 2018, and 69% of injuries among INDOT employees involved were road maintenance workers. These statistics emphasize the need to reduce the time that crews spend in close proximity to traffic, moving equipment, confined spaces, weather-related hazards, and other high-risk conditions.

At the same time, maintenance demand has increased. From 2009 to 2022, Indiana lane miles increased from 198,265 to 203,238, and total miles traveled increased from 24,533 million to 34,946 million. During the same period, the number of road maintenance workers in Indiana decreased from 4,880 to 4,080 (U.S. Bureau of Labor Statistics, 2025; Federal Highway Administration, 2026). These trends motivate technologies that can supplement field crews, reduce high-risk exposure, and support maintenance productivity.

Autonomous maintenance technologies (AMTs) are a potential remedy to these challenges. Recent advances in vehicle automation, wireless communication, artificial intelligence (AI) and machine learning, robotics, and sensing have made it possible to automate portions of road maintenance tasks. However, AMTs differ widely in maturity, operational context, cost, risk, and acceptance.

1.2 Research Objectives

The objective of this project is to explore the feasibility of deploying various AMTs in INDOT road maintenance activities. The feasibility study examines the market for existing technologies, deployment feasibilities, and human-machine interactions. The end goal is to provide INDOT with recommendations on deployment requirements, readiness, and pilot sequencing for different AMTs.

The study builds on prior INDOT project on autonomous truck-mounted attenuators (ATMAs), which investigated feasibility, deployment considerations, worker perception, and cost-benefit issues for one specific AMT category (Tian et al., 2022). This study broadens that scope to multiple AMT categories and evaluates how they may fit INDOT maintenance operations.

1.3 Candidate Technologies

The research team uses INDOT maintenance activity data, man-hours, injury exposure, expected cost savings, and proximity to field deployment as screening criteria. The following lists the eight AMT categories considered in the project scope:

- Autonomous snowplowing
- Autonomous pothole patching

- Autonomous crack sealing
- Automated traffic control device setup and retrieval
- Autonomous mowing
- Autonomous roadway sweeping
- Autonomous culvert inspection
- Automated inspection technology

1.4 Business Case

This project may benefit INDOT in multiple aspects. First, AMTs can reduce worker exposure in high-risk environments such as live traffic, mobile work zones, winter operations, steep slopes, and confined spaces such as drainage assets and pipes. Second, AMTs may improve productivity by allowing crews to complete repetitive or hazardous tasks with less manual exposure and more consistent task execution. Third, AMTs can support longer term workforce resilience by helping INDOT manage growing maintenance demand despite labor-market constraints.

The project also provides a synthesis base for future AMT research and pooled-fund efforts. Because AMT markets are rapidly developing and technology readiness varies by application, INDOT needs a structured way to distinguish near-term pilots from technologies that should be monitored or tested only in controlled environments.

1.5 Report Organization

The rest of the final report is organized as follows. Chapter 2 presents current deployment of ATMs. Chapter 3 synthesizes the technology inventory. Chapter 4 presents the preacceptance survey, and Chapter 5 provides conclusions and recommendations.

2. CURRENT DEPLOYMENT OF AUTONOMOUS MAINTENANCE TECHNOLOGIES

2.1 Purpose and Approach

This chapter investigated AMT adoption and experience in other state departments of transportation (DOTs) and surveyed recent developments in relevant maintenance technologies. The intent was to identify which technologies have moved beyond concept-stage demonstrations, what tasks they support, what deployment challenges agencies have encountered, and which technology categories may benefit INDOT in the future.

The first component is an AMT Utilization and Impact Assessment Survey of state DOTs. The survey gathered information on adoption of AMTs, number of units, costs, vendors, deployment stage, benefits, drawbacks, barriers, and agency ranking of technology needs. A summary of survey structure is shown in Table 2.1 and the complete survey body is provided in Appendix A.

2.2 State DOT Survey Finding Summary

Ten DOTs participated in the survey from the states of Oklahoma (ODOT), Minnesota (MnDOT), Nevada (NDOT), Utah (UDOT), North Dakota (NDDOT), Michigan (Michigan DOT), Iowa (Iowa DOT), Tennessee (TDOT), Kentucky (KYTC), and Mississippi (Mississippi DOT). Six DOTs completed the

TABLE 2.1
State DOT AMT Utilization Survey Structure.

Survey Section	Information Collected
Key technologies	Snowplowing, pothole patching, crack sealing, cone setup, mowing, roadway sweeping, culvert inspection, and inspection technology.
Technology-specific information	Number of units, initial costs, annual maintenance costs, vendor information, operational tasks, deployment stage, potential benefits, drawbacks, and challenges.
Additional information	Other AMTs used by the agency and technology-need rankings.
Demographic data	Name, affiliation, DOT experience, position, and willingness for follow-up.

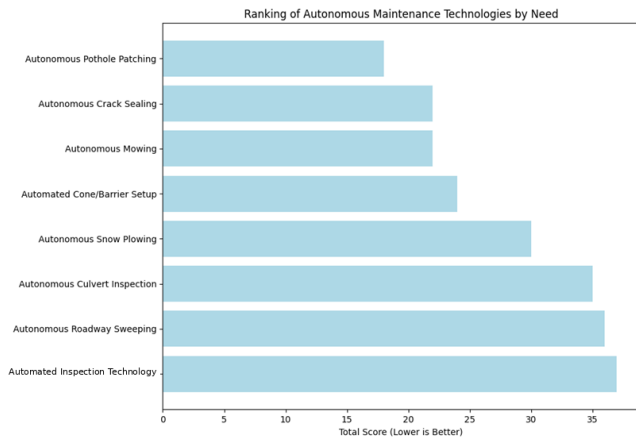


Figure 2.1 Total Scores of AMT Rankings From State DOT Survey; Lower Score Indicates Higher Priority.

AMT prioritization question, ranking technologies from 1 as most needed to 8 as least needed. Figure 2.1 shows the total scores, where lower scores indicate higher priority. The highest-priority AMTs in this state DOT sample are autonomous pothole patching, autonomous crack sealing, and autonomous mowing.

The survey also reveals important variation in how agencies interpret automation. A MnDOT respondent described a strategy focused on operator-assist systems rather than full autonomy, including drone-assisted inspections and driver-assistance systems for snowplowing. This perspective is relevant for INDOT because it suggests that near-term AMT adoption can emphasize human-in-the-loop assistance, decision support, and exposure reduction rather than full worker replacement.

UDOT expressed interest in ATMA vehicles for paint crew moving operations in the Salt Lake City area. This is consistent with broader national attention to ATMAs as a work-zone safety technology that removes the truck-mounted attenuator (TMA) driver from one of the highest-risk positions in mobile work zones (Bennett & Lasky, 2022; Kohls, 2020).

Among survey respondents, NDDOT, Michigan DOT, and TDOT reported using autonomous culvert inspection technologies, and Iowa DOT and Mississippi DOT reported use of automated inspection technologies. An example of the NDDOT deployment of autonomous culvert inspection is summarized in

TABLE 2.2
NDDOT Autonomous Culvert Inspection Deployment Summary.

Category	Details
Fleet size	Approximately 13 inspection vehicles of varying complexity
Initial cost	Smaller crawlers: approximately \$1,500/unit; Larger commercial unit, such as Pearpoint P350 crawler system: approximately \$60,000/unit
Annual maintenance	Approximately \$500/unit for replacement parts and upgrades
Vendors/equipment	Smaller vehicles are homemade; Larger vehicles include Pearpoint P350 crawler systems with upgrades for longer or more complex culverts
Applications	Project development, planning, emergency inspections, and inventory needs
Implementation stage	Beyond pilot/research stage; All districts are using the technology, but not yet full-scale implementation
Benefits	Reduces need to enter confined spaces and provides a more complete view inside culverts
Challenges	Training, standardization of equipment/processes, asset and data management, time/labor required for comprehensive inspection, and staffing constraints

Table 2.2. The case illustrates that autonomous culvert inspection can be implemented in a practical, district-level manner with a mixture of low-cost homemade units and more capable commercial crawlers.

2.3 Recent Developments in AMTs

So far, the most popular AMT that has been tested and/or deployed is the ATMA system. Kratos Defense and Security Solutions pioneered the deployment of the world's first ATMA in 2017 (American Association of State Highway and Transportation Officials [AASHTO], n.d.). Their system features component redundancy, active safety mechanisms, high-accuracy navigation, encrypted vehicle-to-vehicle communications, and multimodal obstacle detection. Their ATMA system operates driverless by following a human-driven leader vehicle, transmitting Global Positioning System (GPS) data to ensure precise path replication. This innovation aims to eliminate the need for a TMA driver, thereby enhancing safety and reducing potential liabilities. The adoption of ATMA technology represents a significant advancement in work-zone safety, particularly for mobile operations like painting road markings. By removing drivers from the rear-most protective vehicles, agencies can reduce the risk of injury and enhance overall safety for road maintenance crews. In 2017, the Colorado Department of Transportation (CDOT) initiated an AMT pooled-fund study aimed at enhancing work-zone safety by deploying self-driving vehicles to enhance safety during maintenance operations (Hu et al., 2022). In 2018, the Missouri Department of Transportation (MoDOT) awarded a contract to acquire two ATMA vehicles for work-zone maintenance, with the objective of thoroughly testing and implementing autonomous maintenance technology within the state

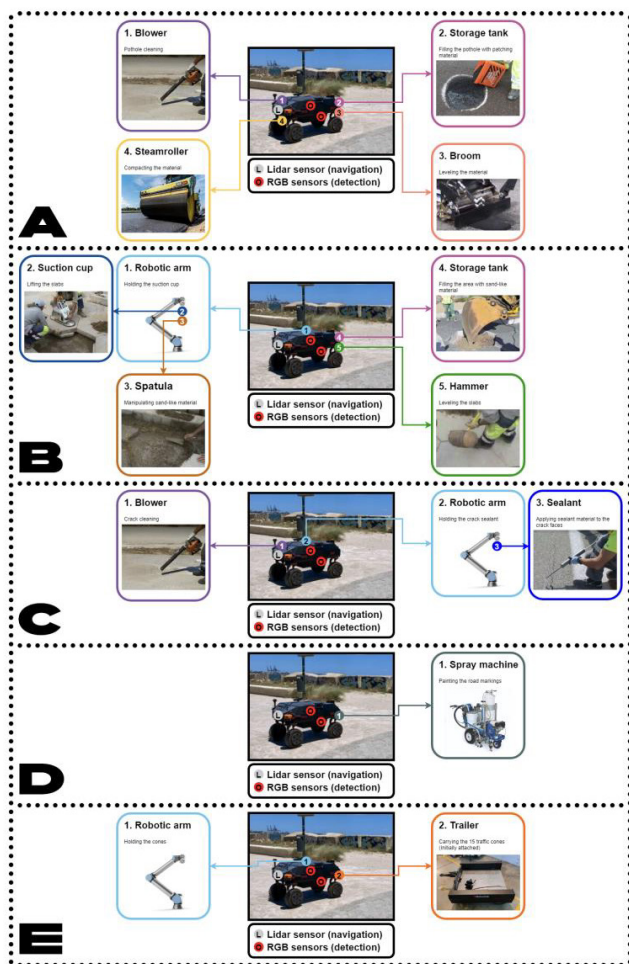


Figure 2.2 The Main Maintenance Procedures That Will Be Performed by the HERON System: (A) Patching Potholes, (B) Replacement of CUD Elements, (C) Sealing Cracks, (D) Painting Blurred Road Markings, and (E) Dispensing and Removing Traffic Cones in an Automated and Controlled Manner (Katsamenis et al., 2022).

(MoDOT, 2025). In 2019, the University of Tennessee’s Center for Transportation Research announced a pilot demonstration to assess the potential of autonomous systems in improving work-zone safety (Kohls, 2020). Similarly, the California Department of Transportation (Caltrans) has been actively involved in evaluating and implementing ATMA technology to enhance work-zone safety (Bennett & Lasky, 2022). In collaboration with the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center at the University of California, Davis, Caltrans identified and procured an operational ATMA system from Royal Truck & Equipment, a leading manufacturer in this field. Recently, INDOT also conducted a pilot study to investigate the impacts of ATMA on INDOT work-zone safety, mobility, and worker productivity (Tian et al., 2024). Other than painting, five other maintenance activities are tested with ATMA including (1) sweeping, (2) trash pickup, (3) crack sealing, (4) underdrain inspection, and (5) Raised Pavement Marker (RPM) inspection. The ATMA system was successfully implemented

in four mobile work-zone operations except for crack sealing. INDOT workers are comfortable operating the ATMA system after training and believe this new technology can improve their safety and productivity.

Another major effort is the HERON project (Katsamenis et al., 2022), funded under the European Union’s Horizon 2020 program, which aims to develop an integrated automated system for road maintenance and upgrades. It focuses on enhancing efficiency and safety in road infrastructure management through a combination of autonomous ground robotic vehicles and drones. These robotic systems perform various maintenance tasks, including crack sealing, pothole patching, dispensing and removing traffic cones, replacement of curb, utility, and drainage (CUD) elements, and road marking, as shown in Figure 2.2. The HERON system incorporates advanced sensing, AI, and robotic automation to conduct pre- and post-maintenance inspections, ensuring precise interventions with minimal disruption to traffic. A recent follow-up study (Katsamenis et al., 2023a) from this project explores the use of deep learning models, specifically transformers, in detecting and segmenting potholes on road surfaces, which pose significant safety risks and can damage vehicles. The research focuses on employing the Transformer framework to analyze high-resolution images from road inspection vehicles. This approach surpasses traditional U-Net models in segmentation accuracy, achieving an average F1-score close to 80%. The findings demonstrate that this transformer-based method effectively identifies and maps potholes, offering a promising tool to enhance road maintenance and safety. Additionally, the publicly released CrackMap dataset from this study supports further research in automated road maintenance. Another recent follow-up study (Katsamenis et al., 2023b) from the same project utilizes deep learning for pixel-wise semantic segmentation of cracks and potholes by introducing a ResUNet-a learning framework. Experimental results demonstrate superior performance over state-of-the-art models.

3. MARKET ANALYSIS OF AUTONOMOUS MAINTENANCE TECHNOLOGIES

3.1 Technology Inventory and Automation Definitions

This chapter explored 51 AMTs across eight categories. Three automation levels are used to classify technologies: full automation, partial automation, and remote operation. Full automation means the AMT can complete the task without human involvement. Partial automation means the AMT collaborates with humans or requires human input to complete part of the task. Remote operation means a human operator controls the system from a remote location. Table 3.1 summarizes the inventory by category. Detailed information on each AMT can be found in Appendix B.

3.2 Category-Level Assessment

Table 3.2 synthesizes the technology inventory and survey evidence into category-level deployment implications. The goal is not to declare a technology ready or not ready in absolute terms, but to identify plausible use cases, expected benefits, and constraints that should shape pilot design.

TABLE 3.1
Explored AMT Inventory by Category.

AMT Category	Number of Products/ Solutions Identified	Representative Products or Vendors From the Inventory
Autonomous Snowplowing	5	• Yarbo snow blower • Nivoso Robot • Teleo remote-operated snowplow • University of Minnesota snow-plow driver-assist system • Snow AI Eco Dimson R3
Autonomous Mower	12	• Spider Automatrix 2.0 • RC Mowers A-60 • FireFly AMP • Scythe M.52 • Toro GeoLink • Green Line Autonomy/Ventrac
Autonomous Crack Sealing	3	• RMV Robotic Crack Sealer • Pave Robotics Tracer • Georgia Tech Crackfiller;
Autonomous Pothole Patching	6	• Python 5000+ • JCB Pothole Pro • Bergkamp SP5E • Velocity spray injection • LeeBoy Rosco RA-400 • Roadpatcher

(Continued)

TABLE 3.1
Explored AMT Inventory by Category. (Continued)

AMT Category	Number of Products/ Solutions Identified	Representative Products or Vendors From the Inventory
Automated Traffic Control Device Setup/Retrieval	6	• Highway Care Falcon • X-Cone • EPIC Cone Setter • Verdegro AutoCone 2.0 • Raptor 3M; Rumble Hog
Autonomous Sweeping	4	• Trombia Free • WeRide RoboSweeper S1 • Boschung Urban-Sweeper S2.0 • Bucher Municipal/ENWAY CityCat 2020ev Donner
Autonomous Culvert Inspection	6	• RedZone Robotics Solo • Beca PIPE-I • Pearpoint P350 flexitrac • Fiberscope STORMER S3000 • Flyability Elios 3 • MnDOT HIVE.
Automated Roadway Inspection	9	• Pavemetrics LCMS-2 • Greenwood TSD • ROMDAS • Robotiz3d ARRES Eye • APTECH EDGE • Cyclomedia • Blynscy • NCTech; Ricoh

TABLE 3.2
Category-Level Technology Synthesis.

AMT Category	Most Plausible Use Cases	Potential Benefits	Primary Constraints and Pilot Questions
Automated Traffic Control Device Setup/Retrieval	Recurring lane closures, major divided highways, controlled mobile operations	• Direct reduction in worker exposure during one of the most hazardous setup/removal tasks • Consistent device placement • Possible setup-time improvements	• Can the system place devices accurately under current work-zone standards? • How much manual backup is needed • How does it handle tapers, curves, ramps, and irregular road geometries?
Autonomous Culvert Inspection	Inventory, condition assessment, emergency inspections, planning, and hard-to-access drainage assets.	• Reduces confined-space and inaccessible-area exposure • Creates video/image records • Supports asset management.	Fit by culvert size and condition; water/mud/debris; battery life; training; data management; standardization of inspection procedures
Automated Roadway Inspection	Pavement condition, signs, striping, asset inventory, and data-driven maintenance planning.	• Reduces manual field inspection time and cost • Improves data coverage and consistency • Supports GIS/asset management integration.	Accuracy validation; data processing workload; integration with current asset management systems
Autonomous Crack Sealing	Pavement preservation on controlled routes, possibly with ATMA/TMA support.	• Reduced exposure during repetitive sealing work • Improved sealant placement consistency • Reduced material waste • Reduced crew size.	Production rate compared with current crews; crack detection reliability; sealant quality; material usage
Autonomous Pothole Patching	Controlled pilots on lower-speed routes or planned maintenance windows; emergency pothole response support.	• Consistent filling/compaction • Faster response in specific contexts	Patch durability; ability to meet current work standards; pothole preparation/squaring; performance in wet/cold conditions
Autonomous Mowing	Steep slopes, behind guardrails, rest areas, facilities, medians, and niche areas where manual work is risky.	• Reduces slope and roadside exposure • Potential productivity improvement for repeatable areas	Obstacle detection such as roadside debris, ditches, culverts, slopes, guardrails, and public traffic; human supervision ratio considerations
Autonomous Sweeping	Controlled shoulders, urbanized routes, rest areas, depots, or facilities.	• Potential exposure and labor reduction; cleaner shoulders	Large debris, shoulder-width fit, live-traffic interaction, snow/ice remnants, route mapping, and maintenance of sweeping mechanisms
Autonomous Snowplowing	Closed sites, campuses, lots, depots; driver-assist systems in public-road winter operations.	• Potential to reduce driver exposure and supplement labor in high-demand events	Operational complexity: poor visibility, extreme cold, snow/ice variability, and equipment reliability

3.3 Cross-Cutting Deployment Considerations

Across the inventory, several feasibility dimensions come forward. These dimensions should be used to evaluate candidate pilots and vendor demonstrations.

- **Technology feasibility:** Sensor performance, mapping/global navigation satellite system needs and reliability, perception reliability, remote-operation latency, autonomy boundaries, fail-safe behavior, and cybersecurity considerations.
- **Operational feasibility:** Compatibility with current work performance standards, required crew size, setup/teardown time, work-zone requirements, traffic-control integration, and manual fallback procedures.
- **Financial feasibility:** Acquisition cost, annual maintenance cost, operator training time, spare parts, support contracts, downtime, and cost per unit of work.
- **Legal and regulatory feasibility:** Permits, operating restrictions, public-road use, liability, data retention, privacy, and procurement requirements.
- **Risk analysis:** Worker safety, public safety, equipment failures, software/sensor errors, low-visibility performance, degraded GPS, and field support requirements.
- **Interoperability:** Potential coordination among AMTs, such as pairing ATMA with other AMTs such as crack sealing, sweeping, or control device setup technologies.

3.4 Implications for Technology Readiness

The inventory suggests that technology readiness should be considered at the level of a specific use case, not merely at the product category level. For example, autonomous mowing may be more practical at a rest area or on a fenced facility than along a high-speed shoulder with slopes, debris, and drainage structures. Similarly, autonomous snowplowing may be more feasible in a closed lot or facility than on an interstate during a low-visibility storm.

Based on the inventory and the market analysis, the strongest near-term candidates are those that either reduce worker exposure without requiring full autonomy or supporting data collection, inventory, and asset management. This logic supports prioritizing traffic control device setup/retrieval, culvert inspection, and roadway inspection for near-term pilots, while trying pilot study or demonstrations for other AMTs, which is consistent with the preacceptance survey results presented in the next section.

4. PREACCEPTANCE SURVEY

4.1 Survey Design

The preacceptance survey gathered structured feedback from INDOT employees regarding perceived feasibility, value, risks, and adoption barriers for selected AMTs. The survey was designed to inform prioritization of AMTs for further evaluation, pilot testing, and phased adoption within INDOT maintenance operations. Table 4.1 provides a survey design summary. The complete survey body is included in Appendix C.

The survey evaluated eight technologies: autonomous crack sealing, autonomous pothole patching, autonomous mowing,

TABLE 4.1
INDOT Preacceptance Survey Design Summary.

Survey Component	Description
Target Respondents	INDOT maintenance personnel and supervisory staff.
Distribution	Established in INDOT SuccessFactors as an optional learning item beginning March 26, 2026; sent to 890 employees, including Highway Technicians, Maintenance Operations Supervisors, Sub District Operations Managers, and Heavy Equipment Operators.
Responses	73 responses received as of April 30, 2026.
Response Format	Likert-scale ratings, ranking questions, and open-ended responses.
Key Evaluation Dimensions	Safety, productivity, traffic disruption, accuracy/data quality, practicality, integration feasibility, and adoption support.

autonomous traffic control device setup, autonomous snowplowing, autonomous sweeping, autonomous culvert inspection, and automated roadway inspection. Each technology was evaluated with a consistent set of Likert-scale questions addressing safety, productivity, traffic disruption, accuracy or data quality, Indiana practicality, integration feasibility, and district support. Respondents also ranked risks and barriers and provided open-ended feedback.

4.2 Data and Analysis Method

The survey dataset contained 73 completed response rows, with item-level valid counts varying because some individual questions were left blank. Likert responses were reverse-coded for interpretability: Strongly agree = 5, Agree = 4, Neutral = 3, Disagree = 2, and Strongly disagree = 1. Thus, higher scores indicate stronger agreement or support. Rank-order questions were analyzed in the original direction, where rank 1 indicates the highest perceived risk or barrier.

4.3 Respondent Profile

The respondent pool was predominantly front-line maintenance personnel. Figure 4.1 show that 49 of 73 respondents were maintenance workers, 13 were crew leaders, and 11 were in other roles. More than half of respondents had less than 5 years of roadway maintenance or operations experience (Figure 4.2), and familiarity with AMTs was limited: only four respondents reported being very familiar (Figure 4.3).

4.4 Overall Attitudes Toward AMTs

Respondents were more likely to view AMTs as important for the future than to support adoption immediately. Among respondents with nonblank final answers, 52 of 72 (72.2%) rated AMTs as very or somewhat important for future operations. However, only 30 of 72 (41.7%) were very or somewhat supportive of adoption, while 19 (26.4%) were neutral and 23 (31.9%) were not supportive. Figure 4.4 illustrates this gap.

This finding suggests that respondents are not rejecting the idea that AMTs may matter. Rather, many are not yet convinced

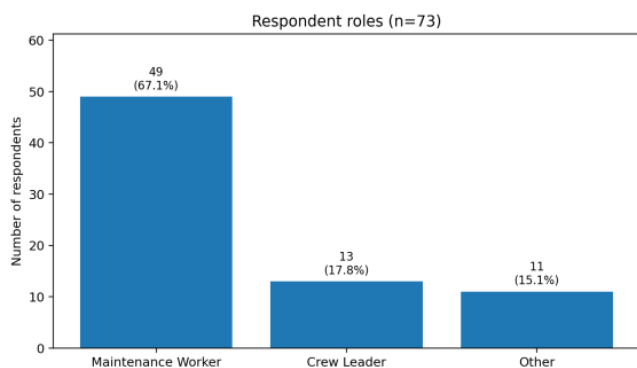


Figure 4.1 Respondent Role Distribution.

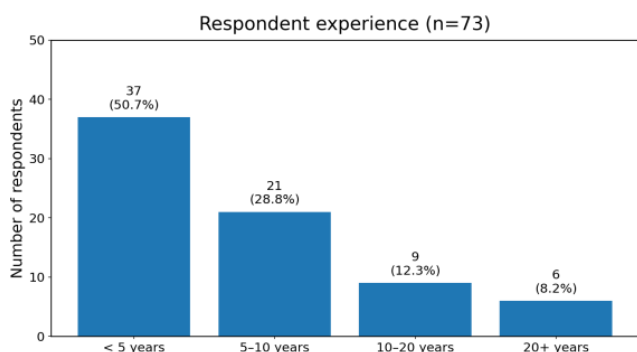


Figure 4.2 Respondent Experience Distribution.

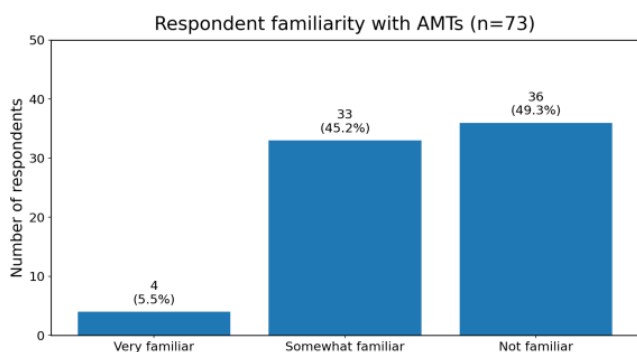


Figure 4.3 Respondent Familiarity With AMT Distribution.

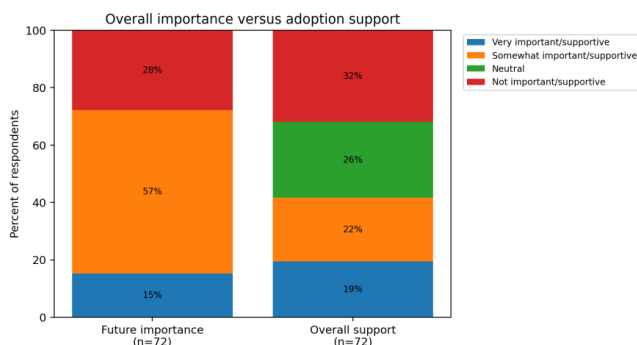


Figure 4.4 Overall Future Importance Compared With Overall Adoption Support.

that adoption will be safe, practical, cost-effective, or beneficial for workers. Future importance and overall support were strongly associated, indicating that workers who see AMTs as strategically important are much more likely to support adoption.

4.5 Technology-Specific Acceptance

Technology acceptance varied significantly across the eight AMTs. As shown in Table 4.2 and Figure 4.5, the top group consisted of traffic control device setup, culvert inspection, and roadway inspection. Snowplowing was significantly lower than every other AMTs and fell below the neutral midpoint on the acceptance index.

The criterion-level results in Figure 4.6 show why the top technologies are stronger candidates. Traffic control device setup had the highest safety favorability rate, and inspection technologies showed relatively high support for practicality, integration, and district adoption. Snowplowing had low favorability percentages across all criteria.

District-level support followed a similar pattern, as shown in Figure 4.7. Traffic control device setup had the highest favorable district support rate (58.0%), followed by culvert inspection (53.0%) and roadway inspection (50.0%). Snowplowing had the lowest favorable rate (24.2%) and the highest negative support rate (53.0%).

4.6 Ranked Risks and Adoption Barriers

Risk rankings were dominated by cost. High cost was ranked as the number one risk in 62.2% of completed risk rankings and had the lowest mean rank (1.69), far ahead of limited flexibility, technological dependence, skill gaps, and complex maintenance. Technology-related issues were the leading adoption barrier, followed by implementation difficulty and legislation/policy issues. Figure 4.8 and Figure 4.9 summarize these results.

Table 4.3 further breaks down risks and barriers by technologies. It shows that high cost was the top risk by mean rank for every technology. Technology-related issues were the top barrier for most AMTs, while pothole patching was the one category where difficulty implementing or incorporating into existing practice ranked as the top barrier.

4.7 Open-Ended Response Themes

Open-ended responses reinforced the quantitative findings. There were 308 nonblank open-ended entries across technology-specific benefits, drawbacks, barriers, training needs, recommendations, and the final “most beneficial AMT” question. The most common themes included practicality and site-fit constraints, opposition or no perceived benefit, training/resources needed, job security or workforce displacement, and technical reliability/support/maintenance.

Crack sealing received the most final open-ended mentions as a beneficial technology, despite its moderate acceptance-index rank. This suggests that a subset of respondents sees a direct labor-exposure benefit in crack sealing, even though broader

TABLE 4.2
Technology Acceptance Summary.

Technology	N	Acceptance Mean (95% CI)	District Support (Higher Is Better)	Safety (Higher Is Better)	Practicality (Higher Is Better)	Integration (Higher Is Better)
Traffic Control Device Setup	69	3.51 (3.22–3.80)	58.0%	63.8%	52.2%	49.3%
Culvert Inspection	66	3.48 (3.21–3.75)	53.0%	51.5%	48.5%	51.5%
Roadway Inspection	66	3.46 (3.17–3.75)	50.0%	53.0%	54.5%	48.5%
Sweeping	68	3.32 (3.03–3.60)	47.1%	50.0%	42.6%	38.2%
Crack Sealing	72	3.31 (3.04–3.58)	45.7%	62.5%	38.0%	42.3%
Pothole Patching	69	3.16 (2.90–3.42)	41.2%	50.7%	35.3%	36.8%
Mowing	68	3.12 (2.85–3.40)	35.3%	41.2%	32.4%	35.3%
Snowplowing	66	2.45 (2.13–2.78)	24.2%	22.7%	24.2%	24.2%

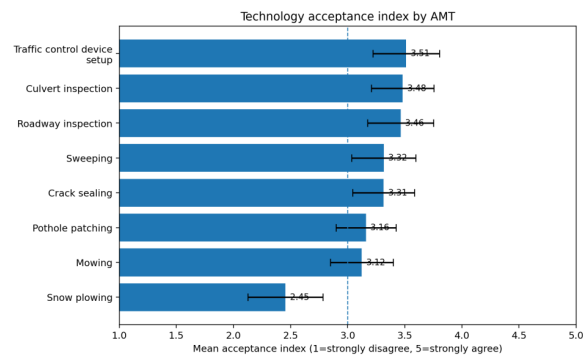


Figure 4.5 Mean Technology Acceptance Index With Approximate 95% Confidence Intervals.

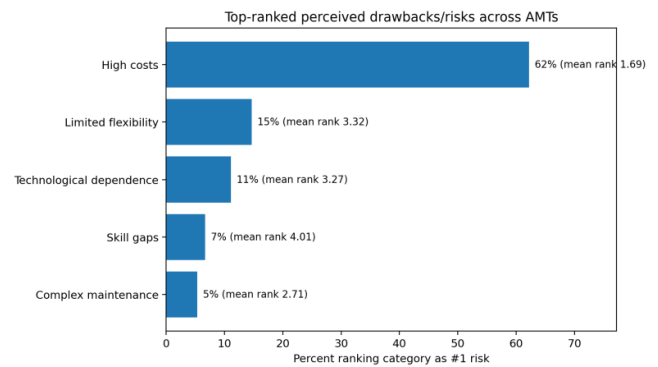


Figure 4.8 Top-Ranked Perceived Risks Across AMT.

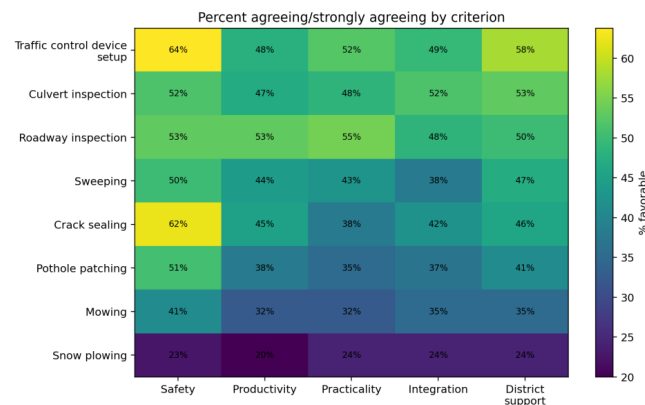


Figure 4.6 Percent Agreeing or Strongly Agreeing by Technology and Decision Criterion.

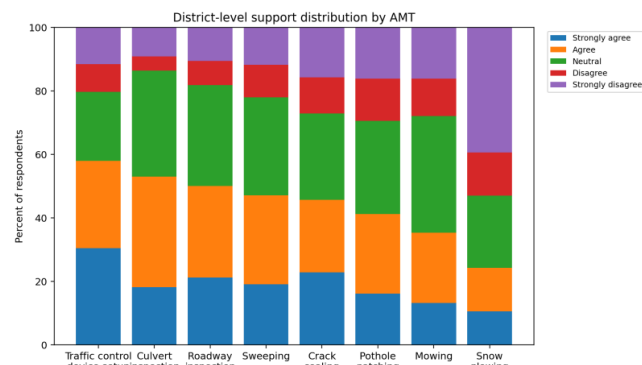


Figure 4.7 District-Level Support Distribution by AMT.

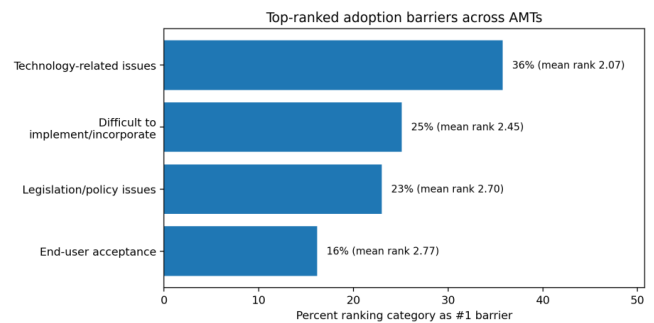


Figure 4.9 Top-Ranked Adoption Barriers Across AMTs.

practicality, productivity, and cost concerns remain. Figure 4.10 summarizes the AMTs named as most beneficial.

Representative comments illustrate both the appeal and the concerns. For traffic control device setup, one respondent emphasized that setting up and tearing down a work zone is among the most dangerous tasks and that eliminating a worker walking with their back to traffic would be valuable. For pothole patching, comments highlighted reduced worker exposure to traffic and shoveling. In contrast, comments about snowplowing emphasized that winter operations require anticipation of road and weather conditions, chemical treatment decisions, and human judgment in dynamic traffic conditions. In addition, most survey participants operate snowplows on public roadways while the autonomous snowplow technology described in the

TABLE 4.3
Most Salient Risk and Barrier by Technology.

Technology	Top Risk by Mean Rank	Risk Mean Rank	% Risk Ranked #1	Top Barrier by Mean Rank	Barrier Mean Rank	% Barrier Ranked #1
Crack Sealing	High costs	1.58	65.8%	Technology-related issues	2.25	36.4%
Pothole Patching	High costs	1.42	74.2%	Difficult to implement/incorporate	2.24	32.4%
Mowing	High costs	1.68	67.9%	Technology-related issues	2.07	31.0%
Traffic Control Device Setup	High costs	1.92	56.0%	Technology-related issues	1.81	40.7%
Snowplowing	High costs	1.96	46.2%	Technology-related issues	2.00	40.7%
Sweeping	High costs	1.56	63.0%	Technology-related issues	2.15	30.8%
Culvert Inspection	High costs	1.62	62.5%	Technology-related issues	1.92	41.7%
Roadway Inspection	High costs	1.88	57.7%	Technology-related issues	1.92	37.5%

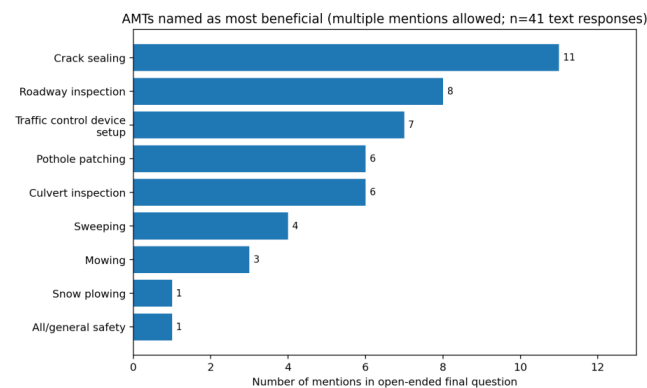


Figure 4.10 AMTs Named as Most Beneficial in Open-Ended Responses.

survey is mainly designed for parking lots and facilities. This inconsistency may partially lead to lower perception and acceptance of the technology in the survey. Job loss, technical support delays, and field-support availability were recurring concerns across categories.

4.8 Survey Summary

Based on the survey results, the following observations are made.

- **Acceptance is cautious and technology-specific:** Respondents recognize that AMTs may be important for future operations, but support is not universal and depends on perceived task fit.
- **Top near-term candidates align with safety/data value:** Traffic control device setup, culvert inspection, and roadway inspection had the strongest acceptance/support profiles.
- **Snowplowing requires restraint:** Autonomous snowplowing had the lowest acceptance index and highest negative district-support rate. However, the low acceptance rate may be caused by the discrepancy between the technology description and participants' expectations.
- **Cost and technical reliability dominate risk perception:** High cost was the leading risk, while technology-related issues were the leading barrier.
- **Workforce trust is a deployment requirement:** Job displacement and job identity concerns should be treated as implementation risks, not merely communication issues.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Overall Conclusions

The project findings support a central conclusion: AMT adoption should be staged, human supervised, and technology specific. The current deployment status, technology inventory, and preacceptance survey all point to the same pattern. AMTs are not a single class of equally ready technologies. Some applications, especially traffic control device setup/retrieval, culvert inspection, and automated roadway inspection, provide clear safety or productivity benefits and appear suitable for near-term pilots. Other technologies have potential but require constrained pilots with explicit performance metrics.

The findings also show that technical feasibility alone is insufficient. Adoption will depend on worker acceptance, operational integration, training, vendor support, reliability, total cost, and clearly communicated safety and productivity objectives. Because the preacceptance survey found a substantial gap between perceived future importance and adoption support, INDOT needs to treat workforce trust as a core implementation requirement.

5.2 Recommended Adoption Tiers

Table 5.1 provides the recommended adoption tiers. The tiers combine market readiness, the technology inventory, state DOT evidence, and the INDOT preacceptance survey results.

5.3 Pilot Implementation and Evaluation Matrix

Table 5.2 translates the technologies for near-term deployment into pilot concepts and evaluation metrics. Each pilot should be designed as a learning activity with defined go/no-go criteria, worker feedback loops, and direct comparison with current methods.

5.4 Implementation Requirements

The following implementation requirements should accompany any INDOT AMT pilot or procurement decision:

- **Define the job to be done:** Specify the exact maintenance task, roadway context, speed environment, traffic-control configuration, weather constraints, and manual fallback procedures.

TABLE 5.1
Recommended AMT Adoption Tiers.

Tier	Technologies	Recommended Posture	Rationale
Tier 1: Near-Term Human-in-the-Loop Pilots	• Traffic control device setup/retrieval • Autonomous culvert inspection • Automated roadway inspection	Prioritize pilot scoping, vendor demonstrations, and district-level field trials.	• Strongest acceptance/support patterns • Clear worker safety or productivity value • Compatible with supervised deployment
Tier 2: Targeted Pilots With Explicit Performance Metrics	• Autonomous crack sealing • Autonomous sweeping • Autonomous pothole patching • Autonomous mowing.	Pilot in controlled or carefully selected use cases, with before/after comparison to current practice.	• Moderate acceptance • Potential benefits but greater uncertainty around productivity, quality, terrain, debris, traffic control, and integration

TABLE 5.2
Pilot Implementation and Evaluation Matrix for Near-Term Deployment AMTs.

Technology	Recommended Pilot Scope	Key Evaluation Metrics	Implementation Notes
Traffic Control Device Setup/ Retrieval	Human-supervised deployment/retrieval on recurring lane closures, major divided highways, or controlled mobile operations	• Worker exposure avoided • Setup/retrieval time • Device spacing/taper accuracy • Manual intervention rate • Public/crew safety events • Downtime.	Include maintenance workers and crew leaders in demonstrations; confirm fit with INDOT work-zone standards and manual backup procedures
Culvert Inspection	District-level inspections using crawlers or drones for culverts that currently require high-exposure entry or are difficult to access	• Number of confined-space entries avoided • Inspection coverage • Image/video quality • Defect-detection usefulness • Setup time • Battery/downtime • Data integration	Confirm fit with INDOT standardized inspection protocols
Roadway Inspection	Mobile pavement/asset data collection on representative routes with human review and asset-management integration	• Detection accuracy • False positives/negatives • Cost per mile • Data quality • GIS/asset-system compatibility • Reduction in manual field exposure	Treat as decision support first; define data ownership, retention, and quality assurance procedures

- **Use human-in-the-loop operation as the default:** For near-term pilots, AMTs should supplement crews through supervised autonomy, decision support, or automated subtasks rather than full unsupervised operation.
- **Protect workforce trust:** Communicate that AMTs are intended to reduce hazardous exposure and improve productivity, not replace the maintenance workforce. Include workers in demonstrations, pilot design, and evaluation to observe the technology first hand.
- **Train before deployment:** Provide hands-on training, troubleshooting guidance, software/computer support, emergency-stop procedures, and clear escalation paths.
- **Require vendor support:** Pilot agreements should include service-level expectations for field support, software updates, and incident response.
- **Measure safety and ROI together:** Evaluation should combine total cost with exposure reduction, quality, productivity, downtime, and worker acceptance.
- **Use phased go/no-go criteria:** Expand pilots only when performance thresholds are met (e.g., safety, productivity, quality) under representative field conditions and when worker feedback supports further testing.

5.5 Future Research Needs

Future work should focus on pilot design, operational validation, and acceptance building. The most important research needs are:

1. Develop pilot protocols and go/no-go criteria for the Tier 1 technologies.
2. Evaluate pilot AMT performance under representative Indiana roadway, weather, traffic, and maintenance-workflow conditions.
3. Develop a workforce training and communication program that addresses job displacement concerns and emphasizes human oversight and quality control.
4. Coordinate future AMT pilots with related work-zone automation efforts such as ATMAAs and connected/smart work-zone systems.

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APPENDICES

Appendix A. State DOT AMT Utilization and Impact Assessment Survey Body

Appendix B. AMT Market Analysis

Appendix C. INDOT Pre-Acceptance Survey Body

Appendix A. State DOT AMT Utilization and Impact Assessment Survey Body

This appendix provides the body of the AMT Utilization and Impact Assessment Survey used to gather information from state DOTs.

Autonomous Maintenance Technology (AMT) Utilization and Impact Assessment Survey

Start of Block: Default Question Block

Autonomous Maintenance Technology (AMT) Utilization and Impact Assessment Survey

Background: We (researchers at Purdue University) are working with Indiana Department of Transportation (INDOT) to explore solutions addressing challenges in road maintenance activities including: 1) How to improve worker safety by minimizing their exposure to hazardous working conditions; 2) How to improve the efficiency of the maintenance operations and optimize resource utilization; 3) How to keep up with the increasing demand for maintenance, driven by added lane miles and the aging of existing infrastructure, with a possible overall shrinking workforce in the future.

Objective: This survey aims to explore the adoption of Autonomous Maintenance Technologies (AMTs) in State Departments of Transportation (DOTs) and assesses the potential of incorporating these technologies into INDOT's daily road maintenance operations.

Duration: This survey takes about 5-20 minutes to complete depending on the number of ATMs your agency is deploying.

Participation in this survey is entirely voluntary. You may choose to withdraw at any point without any penalty. Your responses will help inform future studies and practices but will not impact your job security or reputation in any way. While the survey is not anonymous, your data will be handled with strict confidentiality. Only aggregated data will be reported. Should you have any questions or concerns regarding this survey, please feel free to reach out to the Principal Investigator, Dr. Yiheng Feng, or the Data Conductor, Cong Zhang, using the contact details provided below.

PI: Yiheng Feng, Civil and Construction Engineering, Purdue University, feng333@purdue.edu.

Data Collector: Cong Zhang, Civil and Construction Engineering, Purdue University, zhan4314@purdue.edu.

IRB NUMBER: IRB-2024-1313

Your participation and inputs are highly appreciated!

Before start, Please read Constent_Form

Q0.1 I have read the consent form. I agree to take part in this research. I am 18 years of age or older and understand the information above about my participation. (Required*).

- Yes
- No

Q0.2 Please type your name (Required*).

Q0.3 Which DOT are you affiliated with (Required*)?

Q0.4 How many years of experience do you have with your DOT (Required*).

Q0.5 What's your position (Required*)?

Q1 Has your DOT used autonomous technologies in winter operations (utilizing self-driving technology to address snow/ice on roadways, parking lots, etc without human intervention)? [Example video](#) (Required*)

- Yes
- No

Q1.1 How many units in TOTAL of the autonomous snow plows are currently in use?

Q1.2 What was the initial cost (equipment cost + infrastructure installation/modification cost) in TOTAL of acquiring the autonomous snow plowing technology? (Please provide an estimation if you don't have the exact value)(unit:\$)

Q1.3 What are the total annual maintenance costs per unit of the autonomous snow plowing technology? (Please provide an estimation if you don't have the exact value)(unit:\$)

Q1.4 Please provide the name(s) of the vendor(s) that supplied the autonomous snow plowing.

Q1.5 Please describe the daily tasks or operations where the autonomous snow plowing is applied? Please select all that apply.

- Highway Snow Removal: Continuous clearing on major highways.
- Parking Lot Clearing: Efficiently clears large parking areas.
- Sidewalk and Pathway Clearing: Clears pedestrian paths safely.
- Adaptive Real-Time Plowing: Adjusts routes based on snowfall data.
- De-icing and Sanding: Applies materials to prevent ice formation.

- Others _____

Q1.6 Whether it is a pilot/research project or a full implementation?

- Pilot/research project
- Full Implementation

Q1.7 What is/are the benefit(s) of using the autonomous snow plowing? Please rank them by dragging the options.

- Increased Efficiency: Autonomous snow plows can operate continuously without breaks, leading to faster and more consistent snow removal compared to manual operations.
- Enhanced Safety: Reduces the need for human operators in hazardous conditions, such as blizzards or icy roads, minimizing the risk of accidents or injuries.
- Labor Cost Savings: Lowers long-term operational costs by reducing the need for manual labor and potentially decreasing fuel consumption through optimized routes and operations.
- Improved Coverage: Enables snow removal in hard-to-reach or dangerous areas where it might be challenging or risky for human drivers to operate.
- Scalability and Flexibility: Allows for quick deployment of multiple autonomous units across various locations, providing flexibility in response to different snow events and conditions.
- Whether there are any additional benefits?

Q1.8 What is/are the drawback(s) of using autonomous snow plowing? Please rank them by dragging the options.

- High Initial Cost: The development and deployment of autonomous snow plowing systems can be expensive due to the advanced technology and sensors required for safe and efficient operation.
- Limited Adaptability: Autonomous snowplows may have difficulty navigating complex or unpredictable environments, such as narrow urban streets or areas with heavy pedestrian traffic, where human judgment is crucial.
- Complexity of Maintenance: Autonomous systems involve advanced technology, which can be difficult and costly to maintain, requiring specialized knowledge and tools.
- Cybersecurity Risks: Autonomous systems are vulnerable to hacking or other cybersecurity threats, which could potentially disrupt operations or lead to dangerous situations if control over the vehicles is compromised.
- Dependence on GPS and Sensors: Autonomous snow plows rely heavily on GPS and other sensors for navigation and obstacle detection. Poor visibility, heavy snowfall, or sensor malfunctions can compromise the system's effectiveness.
- Whether there are any additional drawbacks?

Q1.9 What hurdles did you encounter during the process? Please choose all that apply.

- Legislation/Policy-related issues
- Technology-related issues
- End-user acceptance
- Difficult to implement/incorporate into existing practice
- Others _____

Q2 Has your DOT used autonomous pothole patching (automatically detecting and repairing potholes)? [Example video](#) (Required*)

- Yes
- No

Q2.1 How many units in TOTAL of the autonomous pothole patching are currently in use?

Q2.2 What was the initial cost (equipment cost + infrastructure installation/modification cost) in TOTAL of acquiring the autonomous pothole patching? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q2.3 What are the total annual maintenance costs per unit for acquiring the autonomous pothole patching? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q2.4 Please provide the name(s) of the vendor(s) that supplied the autonomous pothole patching.

Q2.5 Please describe the daily tasks or operations where the autonomous pothole patching is applied? Please select all that apply.

- Routine Roadway Inspections: Scans roads for defects, identifying repairs.
- Precise Patching Application: Applies patching material efficiently and evenly.
- Real-Time Damage Assessment: Analyzes potholes and selects repair methods.
- Automated Traffic Management: Reroutes traffic to ensure safety during repairs.
- Scheduled Maintenance Runs: Performs maintenance during off-peak traffic hours.
- Others

Q2.6 Whether it is a pilot/research project or a full implementation?

- Pilot/research project
- Full implementation

Q2.7 What is/are the benefit(s) of using the autonomous pothole patching? Please rank them by dragging.

- Increased Efficiency: Faster and more consistent repairs compared to manual labor.
- Cost Savings: Reduces the need for large repair crews and minimizes material waste.
- Improved Safety: Limits human exposure to hazardous conditions, such as working near traffic or in bad weather.
- Minimized Traffic Disruption: Automated systems can work during off-peak hours, reducing the impact on traffic flow.
- Enhanced Accuracy: Precise detection and repair of potholes, ensuring longer-lasting fixes.
- Whether there are any additional benefits?

Q2.8 What is/are the drawback(s) of using the autonomous pothole patching? Please rank them by dragging.

- High Initial Costs: Significant investment required for purchasing and maintaining the technology.
- Limited Adaptability: May struggle with complex or irregular road conditions.
- Technical Malfunctions: Risk of system failures or maintenance issues.
- Job Displacement: Potential reduction in demand for human labor in road maintenance.
- Weather Sensitivity: Performance may be affected by extreme weather conditions like heavy rain or snow.
- Whether there are any additional drawbacks?

Q2.9 What hurdles did you encounter during the process? Please choose all that apply.

- Legislation/Policy-related issues
- Technology-related issues
- End-user acceptance
- Difficult to implement/incorporate into existing practice
- Others _____

Q3 Has your DOT used autonomous crack sealing (identifying and filling cracks in pavement? [Example video](#) (Required*))

- Yes
- No

Q3.1 How many units in TOTAL of acquiring the autonomous crack sealing? (unit:\$)

Q3.2 What was the initial cost (equipment cost + infrastructure installation/modification cost) in TOTAL of acquiring the autonomous crack sealing? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q3.3 What are the total annual maintenance costs per unit for acquiring the autonomous crack sealing? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q3.4 Please provide the name(s) of the vendor(s) that supplied the autonomous crack sealing.

Q3.5 Please describe the daily tasks or operations where the autonomous crack sealing is applied? Please select all that apply.

- Crack Detection: Using sensors or cameras to identify cracks in the pavement.
- Measurement: Assessing crack depth and width to determine the required sealant.
- Surface Cleaning: Clearing debris and moisture from the crack for proper sealing.
- Sealant Application: Precisely applying the sealing material to fill cracks.
- Inspection: Verifying the quality of the seal and checking for any irregularities.

- Others _____

Q3.6 Whether it is a pilot/research project or a full implementation?

- Pilot/research project
- Full implementation

Q3.7 What is/are the benefit(s) of using the autonomous crack sealing? Please rank them by dragging.

- Increased Efficiency: Automation speeds up the crack detection and sealing process, reducing the time required for road maintenance.
- Improved Accuracy: Autonomous systems provide precise application of sealant, minimizing waste and ensuring consistent repairs.
- Cost Savings: Reducing labor and material waste leads to long-term cost savings in road maintenance operations.
- Enhanced Safety: Minimizes the need for human workers in hazardous environments, reducing the risk of accidents.
- Improved Operations: Automation reduces the number of workers per shift and thus enabling simultaneous multiple activities with the existing workforce.
- Whether there are any additional benefits?

Q3.8 What is/are the drawback(s) of using the autonomous crack sealing? Please rank them by dragging.

- High Initial Costs: The equipment and technology required for automation can be expensive to acquire and implement.
- Complex Maintenance: Maintaining and repairing autonomous systems requires specialized knowledge, increasing operational complexity.
- Limited Flexibility: Autonomous systems may struggle with non-standard road conditions or unexpected obstacles that require human judgment.
- Technological Dependence: Reliance on advanced technology can lead to downtime if technical issues or software malfunctions occur.
- Skill Gaps: Operators may need additional training to manage and troubleshoot autonomous systems effectively, which can be a barrier in some regions.
- Whether there are any additional drawbacks?

Q3.9 What hurdles did you encounter during the process? Please choose all that apply.

- Legislation/Policy-related issues
- Technology-related issues
- End-user acceptance
- Difficult to implement/incorporate into existing practice
- Others _____

Q4 Has your DOT used automated cone/barrier setup (automating the placement and/or removal of traffic cones and/or barriers)? [Example video](#) (Required*)

- Yes
- No

Q4.1 How many units in TOTAL of the automated cone/barrier setup are currently in use? (unit:\$)

Q4.2 What was the initial cost (equipment cost + infrastructure installation/modification cost) in TOTAL of acquiring the automated cone/barrier setup? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q4.3 What are the total annual maintenance costs per unit for acquiring the automated cone/barrier setup? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q4.4 Please provide the name(s) of the vendor(s) that supplied the automated cone/barrier setup.

Q4.5 Please describe the daily tasks or operations where the automated cone/barrier setup is applied? Please select all that apply.

- Work Zone Setup: Deploying cones and barriers to mark construction or maintenance zones on highways or streets, ensuring safe traffic management.
- Lane Closures: Automating the placement of cones or barriers to safely close lanes during roadwork or accidents, reducing the need for manual labor.
- Event Traffic Control: Setting up traffic cones and barriers for large events, such as concerts or sports games, to manage vehicle flow efficiently.
- Incident Management: Quickly deploying barriers or cones in response to accidents or emergencies to protect the scene and redirect traffic.
- Temporary Detours: Creating detours for vehicles using automated systems to place cones and barriers along alternate routes during road closures.
- Others _____

Q4.6 Whether it is a pilot/research project or a full implementation?

- Pilot/research project
- Full Implementation

Q4.7 What is/are the benefit(s) of using the automated cone/barrier setup is applied? Please rank them by dragging.

- Increased Safety: Reduces the need for workers to be physically present in hazardous environments like highways, minimizing the risk of accidents.
- Enhanced Efficiency: Speeds up the deployment and removal of cones and barriers, saving time during roadwork or emergency responses.
- Labor Cost Savings: Over time, automation reduces labor costs and improves resource management.
- Consistency: Ensures cones and barriers are placed accurately and consistently, improving overall traffic management and safety.

- Minimized Traffic Disruption: Faster setup reduces the duration of lane closures and detours, minimizing inconvenience for drivers.
- Whether there are any additional benefits?

Q4.8 What is/are the drawback(s) of using the automated cone/barrier setup is applied? Please rank them by dragging.

- High Initial Cost: Automated systems and equipment for setting up cones and barriers can be expensive to purchase and implement.
- Limited Adaptability: These systems may struggle with unexpected obstacles, uneven terrain, or non-standard road layouts that require human intervention.
- Technical Malfunctions: Any failure in the automation system can lead to delays in deployment or improper setup, compromising safety.
- Maintenance Complexity: Keeping the automated equipment in working order requires specialized skills and regular maintenance.
- Job Displacement: Automation may reduce the need for manual labor, potentially impacting workers who traditionally handle these tasks.
- Whether there are any additional drawbacks?

Q4.9 What hurdles did you encounter during the process? Please choose all that apply.

- Legislation/Policy-related issues
- Technology-related issues
- End-user acceptance
- Difficult to implement/incorporate into existing practice
- Others _____

Q5 Has your DOT used the autonomous mowing (automatically maintaining grassy areas along roadways or around facilities)? [Example video](#) (Required*)

- Yes
- No

Q5.1 How many units in TOTAL of the autonomous mowing are currently in use? (unit:\$)

Q5.2 What was the initial cost (equipment cost + infrastructure installation/modification cost) in TOTAL of acquiring the autonomous mowing? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q5.3 What are the total annual maintenance costs per unit for acquiring the autonomous mowing? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q5.4 Please provide the name(s) of the vendor(s) that supplied the autonomous mowing.

Q5.5 Please describe the daily tasks or operations where the autonomous mowing is applied? Please select all that apply.

- Highway and Roadside Maintenance: Mowing grassy areas along highways and roadways to maintain safety and aesthetics.
- Facility Maintenance: clearing and maintaining the grass within DOT facilities.
- Rest Area Upkeep: Mowing green spaces and landscaping in highway rest areas to keep them tidy.
- Public Right-of-Way Maintenance: Mowing areas within public rights-of-way to prevent overgrowth and ensure accessibility.
- Median and Embankment Management: Mowing vegetation in road medians and embankments for safety and visual appeal.
- Others _____

Q5.6 Whether it is a pilot/research project or a full implementation?

- Pilot/research project
- Full implementation

Q5.7 What is/are the benefit(s) of using the autonomous mowing is applied? Please rank them by dragging.

- Increased Efficiency: Autonomous mowers can operate continuously without human intervention, covering large areas quickly and efficiently.
- Labor Cost Savings: Reduces labor costs associated with manual mowing and maintenance of traditional mowing equipment.
- Consistent Results: Provides uniform mowing and maintenance, ensuring an even cut across the entire area.
- Enhanced Safety: Reduces the risk of injury to workers by eliminating the need for manual handling of heavy or dangerous equipment.
- Reduced Environmental Impact: Modern autonomous mowers often use electric power, which can be more environmentally friendly compared to gasoline-powered mowers.
- Whether there are any additional benefits?

Q5.8 What is/are the drawback(s) of using the autonomous mowing is applied? Please rank them by dragging.

- High Initial Cost: Autonomous mowers can be expensive to purchase and install, requiring a significant upfront investment.
- Limited Capability in Complex Terrain: These mowers may struggle with uneven, steep, or complex terrains, reducing their effectiveness in certain environments.
- Technical Issues: Dependence on advanced technology means that malfunctions or software issues can disrupt mowing operations.
- Maintenance Requirements: While they reduce manual labor, autonomous mowers still require regular maintenance and repairs, which can be costly and require specialized knowledge.
- Weather Dependency: Autonomous mowers may be limited by weather conditions, such as heavy rain or snow, which can affect their performance and operational reliability.
- Whether there are any additional drawbacks?

Q5.9 What hurdles did you encounter during the process? Please choose all that apply.

- Legislation/Policy-related issues

- Technology-related issues
- End-user acceptance
- Difficult to implement/incorporate into existing practice
- Others _____

Q6 Has your DOT used autonomous roadway sweeping (cleaning road surfaces by removing debris)? [Example video](#) (Required*)

- Yes
- No

Q6.1 How many units in TOTAL of the autonomous roadway sweeping are currently in use? (unit:\$)

Q6.2 What was the initial cost (equipment cost + infrastructure installation/modification cost) in TOTAL of acquiring the autonomous roadway sweeping? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q6.3 What are the total annual maintenance costs per unit for acquiring the autonomous roadway sweeping? (Please provide an estimation if you don't have the exact value)(unit:\$)

Q6.4 Please provide the name(s) of the vendor(s) that supplied the autonomous roadway sweeping.

Q6.5 Please describe the daily tasks or operations where the autonomous roadway sweeping is applied? Please select all that apply.

- Highway and Freeway Cleaning: Autonomous sweepers are used to maintain major roadways, reducing debris and improving traffic safety.
- Urban Street Sweeping: Ensures cleanliness of municipal streets, improving road conditions and public safety in urban areas.
- Maintenance of Shoulders and Medians: Keeps shoulders and medians free from debris, ensuring safety and preventing obstructions on major roads.
- Rest Area and Parking Lot Cleaning: Maintains cleanliness and safety in rest areas and parking facilities managed by the DOT.
- Roadside Debris Removal: Clears debris from highways and rural roadsides, preventing obstructions and safety hazards for drivers.
- Others _____

Q6.6 Whether it is a pilot/research project or a full implementation?

- Pilot/research project
- Full implementation

Q6.7 What is/are the benefit(s) of using the autonomous roadway sweeping is applied? Please rank them by dragging.

- Increased Efficiency: Autonomous sweepers can operate continuously, covering large areas quickly and effectively without the need for manual intervention.
- Improved Safety: Reduces the risk to human operators by keeping them out of hazardous road environments and busy traffic areas.
- Labor Cost Savings: Lowers labor costs and reduces the need for manual sweeping, resulting in long-term cost efficiency.
- Consistent Results: Ensures uniform and thorough cleaning of roadways, improving overall cleanliness and maintenance.
- Minimized Traffic Disruption: Autonomous sweepers can work during off-peak hours or while traffic continues, reducing the impact on road users.
- Whether there are any additional benefits?

Q6.8 What is/are the drawback(s) of using the autonomous roadway sweeping is applied? Please rank them by dragging.

- High Initial Cost: Significant upfront investment for technology and equipment.
- Technical Issues: Vulnerable to malfunctions and software problems.
- Limited Capability: May struggle with complex or irregular road conditions.
- Maintenance Needs: Requires regular and specialized maintenance.
- Regulation and Laws: Autonomous sweepers must comply with specific regulations to operate on public roads.
- Whether there are any additional drawbacks?

Q6.9 What hurdles did you encounter during the process? Please choose all that apply.

- Legislation/Policy-related issues
- Technology-related issues
- End-user acceptance
- Difficult to implement/incorporate into existing practice
- Others _____

Q7 Has your DOT used autonomous culvert inspection (using autonomous robots or drones to inspect culverts, identifying blockages or structural issues without requiring personnel?

Example video (required*)

- Yes
- No

Q7.1 How many units in TOTAL of the autonomous culvert inspection are currently in use? (unit:\$)

Q7.2 What was the initial cost (equipment cost + infrastructure installation/modification cost) in TOTAL of acquiring the autonomous culvert inspection ? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q7.3 What are the total annual maintenance costs per unit for acquiring the autonomous culvert inspection? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q7.4 Please provide the name(s) of the vendor(s) that supplied the autonomous culvert inspection.

Q7.5 Please describe the daily tasks or operations where the autonomous culvert inspection is applied? Please select all that apply.

- Routine Culvert Condition Monitoring: Regular inspections to assess the structural integrity and functionality of culverts.
- Maintenance Scheduling: Identifying issues that require maintenance or repairs, helping to schedule timely interventions.
- Debris and Blockage Detection: Detecting and reporting blockages or debris that may obstruct water flow or damage the culvert.
- Pre-emptive Inspections: Conducting inspections before and after severe weather events to prevent potential problems and ensure proper drainage.
- Data Collection and Analysis: Gathering and analyzing data on culvert conditions for long-term planning and infrastructure management.
- Others _____

Q7.6 Whether it is a pilot/research project or a full implementation?

- Pilot/research project
- Full implementation

Q7.7 What is/are the benefit(s) of using the autonomous culvert inspection is applied? Please rank them by dragging.

- Increased Efficiency: Automates the inspection process, allowing for quicker and more frequent assessments.
- Enhanced Safety: Reduces the need for human inspectors to enter potentially hazardous or hard-to-reach areas.
- Labor Cost Savings: Lowers labor costs and reduces the need for manual inspection equipment.
- Improved Accuracy: Provides detailed and consistent data on culvert conditions, improving diagnostic accuracy.
- Early Problem Detection: Identifies issues such as blockages or structural damage early, enabling timely maintenance and preventing major repairs.
- Whether there are any additional benefits?

Q7.8 What is/are the drawback(s) of using the autonomous culvert inspection is applied? Please rank them by dragging.

- High Initial Cost: Requires a significant investment in technology and equipment.
- Technical Limitations: May encounter difficulties in inspecting complex or obstructed culverts where maneuverability or sensor effectiveness is limited.
- Maintenance Requirements: Autonomous systems need regular maintenance and calibration to ensure optimal performance.

- Data Handling: Managing and processing large volumes of inspection data can be challenging and require specialized software and expertise.
- Weather and Environmental Constraints: Performance can be affected by adverse weather conditions or challenging environments, which might limit inspection capabilities.
- Whether there are any additional drawbacks?

Q7.9 What hurdles did you encounter during the process? Please choose all that apply.

- Legislation/Policy-related issues
- Technology-related issues
- End-user acceptance
- Difficult to implement/incorporate into existing practice
- Others _____

Q8 Has your DOT used automated inspection technology (using autonomous systems, such as drones or robots, to perform inspections of infrastructure, identifying defects or areas needing repair without direct human involvement)? [Example video](#) (Required*)

- Yes
- No

Q8.1 How many units in TOTAL of the autonomized inspection technology are currently in use? (unit:\$)

Q8.2 What was the initial cost (equipment cost + infrastructure installation/modification cost) in TOTAL of acquiring the automated inspection technology? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q8.3 What are the total annual maintenance costs per unit for acquiring the automated inspection technology? (Please provide an estimation if you don't have the exact value) (unit:\$)

Q8.4 Please provide the name(s) of the vendor(s) that supplied the automated inspection technology.

Q8.5 Please describe the daily tasks or operations where the automated inspection technology is applied? Please select all that apply.

- Overpasses Inspections: Using drones or robots to inspect the structural integrity and condition of overpasses, identifying any cracks, corrosion, or other defects.
- Roadway Surveillance: Monitoring road conditions and detecting issues such as potholes or surface wear using autonomous systems.
- Utility Line Inspections: Inspecting overhead power lines, telecommunications cables, or pipelines to detect wear, damage, or other issues.

- Highway Surface Assessment: Utilizing autonomous systems to evaluate the condition of highway surfaces, including detecting cracks, wear, and surface deterioration.
- Roadway Safety Features Inspection: Using autonomous systems to inspect and maintain safety features such as guardrails, road markings, and signage to ensure they are in good condition and functioning correctly.
- Others _____

Q8.6 Whether it is a pilot/research project or a full implementation?

- Pilot/research project
- Full implementation

Q8.7 What is/are the benefit(s) of using automated inspection technology is applied? Please rank them by dragging.

- Increased Efficiency: Automates inspection processes, allowing for more frequent and thorough assessments with less manual intervention.
- Enhanced Safety: Reduces the need for human inspectors to enter hazardous or difficult-to-reach areas, minimizing safety risks.
- Labor Cost Savings: Lowers long-term operational costs by reducing labor requirements and improving overall inspection efficiency.
- Improved Accuracy: Provides high-resolution imagery and consistent data, leading to more precise identification of defects and issues.
- Timely Problem Detection: Enables early detection of potential problems, allowing for prompt maintenance and reducing the risk of severe damage.
- Whether there are any additional benefits?

Q8.8 What is/are the drawback(s) of using the automated inspection technology is applied? Please rank them by dragging.

- High Initial Cost: Significant investment is required for purchasing and implementing advanced autonomous systems and related technology.
- Technical Limitations: Autonomous systems may struggle with complex or obstructed areas, and their performance can be limited by technical constraints.
- Maintenance Requirements: Requires regular upkeep and calibration to ensure reliable performance, potentially leading to additional operational costs.
- Data Management Challenges: Handling and analyzing the large volumes of data collected by autonomous systems can be complex and require specialized software and expertise.
- Weather and Environmental Constraints: Performance may be affected by adverse weather conditions or challenging environments, potentially limiting the effectiveness of inspections.
- Whether there are any additional drawbacks?

Q8.9 What hurdles did you encounter during the process? Please choose all that apply.

- Legislation/Policy-related issues
- Technology-related issues
- End-user acceptance
- Difficult to implement/incorporate into existing practice

- Others _____

Q9 Is there any other autonomous maintenance technology (AMT) that your DOT is using but not listed here? (Optional)

Q10 Please rank the following technologies in order of need for your agency, with 1 being the MOST needed and 8 being the LEAST needed (Required*). Drag the options to reorder them.

- Autonomous snow plowing
- Autonomous pothole patching
- Autonomous crack sealing
- Automated cone/barrier setup
- Autonomous mowing
- Autonomous roadway sweeping
- Autonomous culvert inspection
- Automated inspection technology
- Others

Q11 If you would like to receive the results of this survey, please provide your email address (Optional).

Q12 Would you be willing to participate in a follow-up interview or provide additional insights on the application of these technologies (Optional)?

- Yes
- No
- Maybe, depending on the circumstances

Q13 Any additional comment that you want to provide? (Optional)

End of Block: Default Question Block

Start of Block: Block 1

Appendix B. AMT Market Analysis

This appendix provides details of each surveyed AMT including vendor information and operational features. Note that this is not a complete list, but representative technologies in each AMT category.

Autonomous Snowplow

Yarbo Snow Blower (full automation and remote operation)

Link: https://www.yarbo.com/products/snow-blower-robot?srsId=AfmBOor8YF2Dou_OaXUxeYhJsuQZ08sH3m2mwChU_PCjtLRese37gS9O

The Yarbo Snow Blower Robot is a modular, autonomous yard-care platform from Yarbo that transforms snow blowing. Fitted with a dedicated Snow Blower Module, it clears up to 12 in (30 cm) of dry, wet, or packed snow across a 24-inch wide path, tossing snow up to 40 ft (12 m) away, all while running on battery power. Designed for hands-free operation, it employs radar and multi-camera obstacle detection, following smart maps and schedules automatically generated from weather forecasts and user input. Housed on rugged rubber tracks and powered by brushless motors, the robot climbs slopes up to 36 % and resists moisture thanks to its IPX6 waterproof rating—ideal for variable winter conditions. Users can control or monitor it via app or remote, and it automatically returns to its docking station for recharging—ensuring constant readiness during snowstorms and preventing accumulation.

Nivoso Robot (remote operation)

Link: <https://nivoso.com/>

The Nivoso Autonomous Outdoor Maintenance Robot is a versatile, modular robotic platform from a University of Minnesota–founded startup, purpose-built for tasks such as snow removal, lawn care, dust control, and hazardous material cleanup. Delivered on-site and deployed via simple integration with a base station, the robot operates in either remote-control or fully autonomous beta modes. Equipped with proprietary sensors, it continuously monitors snow accumulation and activates automatically once predefined thresholds are reached, maintaining safer and more accessible sidewalks during a storm. Battery-powered and rugged, Nivoso can clear a driveway much faster—up to 14× quicker—than manual shoveling, with one unit completing tasks in just 1.5 hours compared to two hours for a team of six. Its intuitive control system allows operation via controller or from inside a vehicle. Nivoso represents a scalable, efficient, and labor-saving leap toward autonomous outdoor maintenance, ready for real-world applications across residential and commercial settings.

Remote-Operated Snowplow (remote operation)

Link: <https://www.teleo.ai/>

The Teleo and Storm Equipment Remote-Operated and Autonomous Industrial Snow Plow is currently the only commercially available system in the U.S. that transforms standard heavy equipment—such as a John Deere 332G skid-steer loader—into a remote-controlled or fully autonomous snow plow. Using Teleo’s Supervised Autonomy retrofit kit and Storm’s Metal Pless snowplow blade, the system enables a single operator in a central command center to remotely

manage mass snow removal in large areas like industrial parking lots, eliminating the need for physical presence in dangerous conditions. Designed to ease staffing pressures and improve efficiency, the platform enables one skilled worker to oversee multiple machines—potentially quadrupling productivity—and opens career opportunities for remote operators. The retrofit is flexible, supporting virtually any heavy equipment make or model, and these machines remain multifunctional year-round, capable of landscaping or freight tasks when not plowing. Remote operations rolled out first, with fully autonomous capabilities deployed in early 2024. In essence, Teleo’s system offers a scalable, safe, and cost-effective solution that enhances productivity, keeps operators out of harm’s way, and adds versatility to existing fleets.

Snowplow driver assist system (partial automation)

Link: <https://cts-d8resmod-prd.oit.umn.edu/pdf/mndot-2023-27.pdf>

To support snowplow operators working in these conditions, University of Minnesota researchers developed a snowplow driver-assist system that provides the operator with visual and auditory information that is suitable for low-visibility situations. A lane-guidance system uses high-accuracy Global Navigation Satellite System (GNSS) and maps of the roadway to provide information to drivers about their lateral positions. A forward-obstacle-detection system uses forward-facing radar to detect potential hazards in the roadway. The design of the system, and in particular its interface, is guided by extensive user testing to ensure the system is easy to understand, easy to use, and well liked among its users.

The system was deployed in two phases over the 2020-2021 and 2021-2022 winter seasons. In total, nine systems were deployed on snowplows across Minnesota, four in the first winter season and an additional five in the second. Participating truck stations represented all eight MnDOT districts as well as Dakota County. Over the course of the deployment, additional user feedback was collected to identify system strengths and areas for improvement. The system was found to be a cost-effective addition to snowplows that increase driver safety, reduce plow downtime, and increase driver efficacy for plowing operations, thus providing support to operators working in demanding, low-visibility conditions.

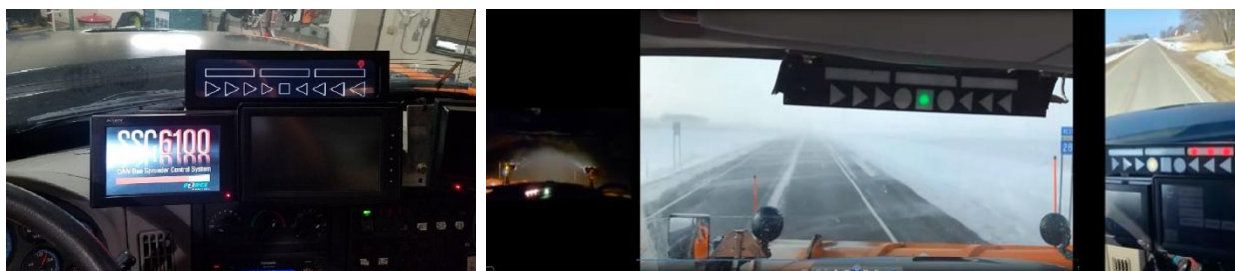


Figure B.1 Snowplow driver assist system – University of Minnesota (Source: <https://cts-d8resmod-prd.oit.umn.edu/pdf/mndot-2023-27.pdf>).

Snow AI Eco Dimson R3 (fully autonomous snow removal fleet)

Link: <https://www.snowaico.com/>

The Eco Dimson R3 from Snow AI is a fully autonomous, battery-powered snow removal system designed for continuous 24/7 winter operations. Equipped with AI, LiDAR, GNSS, and

advanced multi-sensor fusion, the R3 fleet navigates safely even in blizzards, performing large-scale clearing with autonomous vehicles and precision ice management using laser cutters. Complemented by humanoid Tesla bots trained for snow removal, the system handles detailed shoveling, walkway access, and areas unreachable by machines. Sustainable energy integration comes via solar panels and eco-friendly de-icing, while rocket-boosted rapid deployment ensures readiness during severe storms. Real-time 360° reporting allows operators to monitor fleet performance remotely, ensuring reliability, safety, and constant availability across diverse environments.

Key features include:

- 24/7 autonomous operation: AI + LiDAR + GNSS enable continuous clearing in all conditions.
- Fleet approach: Large battery-powered units supported by humanoid Tesla bots for detailed work.
- Advanced snow & ice management: Laser cutters for ice, eco-friendly de-icing systems.
- Sustainability: Solar power integration reduces reliance on grid charging.
- Rapid deployment: Rocket boosters for emergency storm response.
- Smart monitoring: Real-time 360° performance reporting and predictive oversight.

Autonomous Mower

Spider Automatrix 2.0 (Partial Automation)

Link: <https://www.spidernewtech.com/spider-autonomous>

The Spider Automatrix 2.0, developed by Dvořák–SPIDER, is a next-generation remote-controlled and semi-autonomous slope mower engineered specifically for high-risk, large-area vegetation control. Its robust electric drivetrain and four-wheel steering configuration make it particularly effective for roadside embankments, drainage ditches, and hard-to-access slopes encountered in highway maintenance programs. The mower is capable of tackling gradients of up to 55°, providing unparalleled performance on extreme terrain.

Key features of the system include:

- High-slope compatibility: Purpose-built for steep inclines common along interstate shoulders, overpasses, and flood channels, reducing manual intervention and improving worker safety.
- Electric operation: Fully electric powertrain eliminates the need for gasoline or oil, enabling quiet operation with zero local emissions—ideal for environmentally sensitive zones.
- Precision control: Dual-direction mowing, four-wheel drive, and an ultra-low center of gravity allow for tight turning radii, slope stability, and minimal turf disruption.
- Remote and autonomous operation: Operators can control the mower via long-range wireless interface or deploy in semi-autonomous mode for repeatable zone mowing.
- Efficient area coverage: Mows up to 6 acres/hour, with a per-charge capacity of 25 acres, suitable for multi-mile highway medians and interchange loops.

Operationally, the Spider Automatrix 2.0 enables a single DOT technician to remotely manage mowing tasks on slopes traditionally requiring manual brush cutting or high-risk machinery. Its electric architecture aligns with state sustainability goals, and its precision terrain-handling technology drastically reduces operational downtime. DOTs benefit from lower lifecycle costs, increased worker safety, and faster vegetation control, particularly in areas prone to erosion, wildlife hazard zones, and visibility obstruction.

RC Mowers Autonomous Mowing Robot (A-Series – A-60) (Full Automation)

Link: <https://www.rcmowersusa.com/robotic-mowers/autonomous-mowing-robot/>

The RC Mowers A-60 Autonomous Mowing Robot is a professional-grade, fully autonomous mower engineered to reduce labor demands and increase efficiency across large-scale DOT operations—such as highway rest areas, roadside medians, airport grounds, and public campuses. Built with commercial ruggedness and advanced autonomy, the A-60 excels in demanding, open terrain environments.

Key features of the system include:

- Powertrain & chassis:
 - 23.5 hp Kawasaki FX730V gas engine paired with Hydro-Gear ZT-3200 transmission
 - 60" commercial cutting deck, weighing ~1,275 lb and fitting standard landscape trailers
- Autonomy & safety:
 - GPS guidance with RTK precision, onboard LiDAR for obstacle detection
 - 1,000 ft remote-operate/stop range, 360° sensor coverage, safety interlocks halt operation if the operator enters the machine
- Productivity metrics:
 - Mow rate of 1.5–2.5 acres/hour depending on site and configuration (up to 2.2 acres/h noted)
 - 5 gal fuel tank supports sustained operation
- Safety & support system:
 - Automatic and manual parking brakes, operator-authenticated autonomous mode
 - Comes with RC Mowers Success System™—dealer training, in-field onboarding, support network, and maintenance protocol

Operationally, the A-60 enables a single DOT technician to manage multiple units: drive one mower to establish mowing zones, then supervise up to three machines autonomously. The system is optimized for large, open-duty areas such as highway shoulders, rest areas, greenway edges, and campus grounds—significantly reducing manual labor, improving safety, and supporting DOT sustainability through efficient fuel usage and idle reduction.

FireFly Automatrix AMP (Full Automation)

Link: <https://fireflyautomatrix.com/amp-mowers/>

The FireFly AMP (Autonomous Mowing Platform) is a heavy-duty, fully autonomous electric mower designed for high-efficiency turf and roadside vegetation management. Engineered from the ground up to be all-electric, it's well-suited for State DOT operations in environmentally sensitive zones and throughout large roadside corridors.

Key features of the system include:

- Electric powertrain & zero emissions:
 - 24.7 kW total power with four 3.3 kW drive motors in a 4×4 configuration
 - Completely electric—no fuel, oil, or hydraulic systems—minimizing operational leaks and maintenance
- Cutting capacity & productivity:
 - 100" cut width via five-gang reel (or optional rotary AMP-X100)
 - Productivity of ~6 acres/hour, and up to 20–25 acres per charge, reaching 40–75 acres/day with mid-day recharge
- Battery & charging:
 - 48 V, 35 kWh LiFePO₄ battery with ~5,000-cycle lifespan (retaining 80% capacity)
 - Fast-charge options: 2.5 hours @ 14 kW, or standard adapters (240 V/120 V)
- Autonomy & navigation:
 - RTK-GNSS positioning with sub-inch accuracy, supported by QuickPlan™ path planning and FireLink interface
 - Safety sensors and obstacle detection with “Keep-Out Zones,” Smart Start™, and Fairway Mode™ to avoid hazards and enable precise edge control
- Maintenance & design:
 - Servo-lifted cutting units with manual adjustments, eliminating hydraulics
 - Minimal upkeep: gear-lube service every 6–12 months; simpler maintenance than engine-based machines

Operational impact for State DOT operations:

- Quiet and emission-free, ideal for maintenance near roads, schools, and communities.
- High-area productivity and optimized path planning work well for highway medians, ramps, rest areas, and turf management across large zones.
- Advanced safety controls allow unmanned edge mowing with reduced operator risk.
- Electric power and minimal lubrication align with DOT goals for environmental sustainability and cleaner operations.

State DOTs are frequently responsible for the upkeep of extensive landscapes such as interstate rest areas, highway interchanges, and vegetated medians spanning hundreds of miles.

Traditionally, these maintenance activities demand multiple field crews operating diesel-powered mowing equipment and often require intermittent lane closures, posing safety and logistical challenges. The FireFly AMP offers a modern, efficient solution to this problem. By deploying AMP units autonomously at designated rest areas and medians with pre-programmed mowing plans, DOTs can streamline operations. The system's QuickPlan™ interface allows maintenance teams to remotely define safe mowing zones, excluding critical roadside features like sidewalks, signage, and shoulders, thereby minimizing manual oversight. The AMP's electric powertrain

enables on-site overnight charging via standard Level 2 EV infrastructure or solar-powered portable chargers, further reducing the logistical footprint.

Beyond operational convenience, FireFly AMP contributes significantly to environmental and community considerations. Its fully electric, low-noise operation ensures minimal disruption to nearby travelers and residents, particularly in community-adjacent rest areas. By offloading routine mowing tasks to AMP, DOT crews can redirect their focus to technical maintenance or high-risk zones like slopes and embankments. This strategic allocation of resources results in reduced labor hours, elimination of fuel and fluid handling near roadways, and a lower emissions footprint. Importantly, fewer required lane closures enhance safety and reduce traffic disruptions during maintenance periods.

Scythe Robotics M.52 Autonomous Mower (Full Automation)

Link: <https://www.scytherobotics.com/mower>

The Scythe M.52 is a fully electric, autonomous commercial mower built to deliver reliable, high-precision turf maintenance with minimal environmental footprint. Featuring robust all-day battery performance, advanced vision systems, and fleet-level remote management tools, the M.52 is optimized for State DOT use in controlled-access public landscapes, such as rest stops, roundabouts, park-and-ride lots, and visitor centers.

Key Features:

- All-Electric System:
 - Powered by a 15 hp deck motor and 20 hp electric drive system
 - Zero fuel, oil, or hydraulic systems—no fluid leaks or emissions
 - Rated for 50,000 mowing hours—10× that of conventional machines
- Autonomy and Safety:
 - Equipped with 8 cameras, ultrasonic sensors, and 360° safe vision
 - Real-time obstacle detection and auto-stop functions
 - Operates independently without perimeter wires using contour-following algorithms
- Cutting Performance:
 - 52-inch cutting width with professional stripe pattern
 - Handles uneven terrain and tight contours typical of interchange loops and center medians
- Fleet Operations and Diagnostics:
 - Connected to cloud-based control systems for remote dispatch, tracking, and diagnostics
 - “Task Sequences” enable automated multi-zone mowing, reducing on-site human support
 - Fleet interface accessible via mobile app and web dashboard
- Efficiency:
 - Delivers a full workday (8+ hours) on a single charge
 - Recharges in half the time with next-gen Li-ion battery pack

- 20 dB quieter than gas-powered equivalents—ideal for noise-sensitive environments

The Scythe M.52 is highly suited for maintaining turf across State-owned rest areas, welcome centers, administrative buildings, and roundabouts, where safety, quiet operation, and sustainability are top priorities. It allows for night or early-morning mowing without disturbing travelers or staff, and the fleet-based controls make it easy for DOT supervisors to monitor multiple units across dispersed sites. The machine's low maintenance needs and emissions-free operation also support long-term DOT goals for decarbonization and labor efficiency.

Belrobotics BigMow GPS-RTK / Connected Line (Full Automation)

Link: <https://www.belrobotics.com/en/commercial-robotic-lawn-mower>

Belrobotics' BigMow, available in Connected Line and GPS-RTK models, is a heavy-duty commercial robotic mower engineered for expansive turf environments. The Connected Line version autonomously maintains up to 24,000 m² (~6 acres) using perimeter wiring, while the GPS-RTK variant can service up to 75,000 m² (~18.5 acres) wire-free with precision strip mowing. The unit employs floating stainless-steel cutting heads that contour uneven terrain and deliver fine mulching, fertilizing soils naturally and enhancing turf health.

BigMow offers continuous day-and-night operation with ultra-low noise emissions (~52 dB), remote fleet management via tablet or smartphone, anti-theft GPS and geofencing alerts, and energy-efficient performance (approximately €150/year in electricity). Built with robust aluminum chassis, sonar safety sensors, LTE/Wi-Fi connectivity, and self-charging docks, it's designed for reliability and long service life—offering up to twice the lifespan of traditional mowers and 90% lower CO₂ emissions.

The BigMow GPS-RTK model enables wire-free, high-precision strip mowing across interstate medians, park-and-ride lots, highway rest areas, and public green spaces. It is ideal for linear landscapes and large open plots, which eliminates the need for diesel-powered, labor-intensive mowing crews. Using RTK guidance, DOT engineers can autonomously schedule mowing cycles overnight or during low-traffic hours to minimize disruption. The system's low noise and zero-emissions operation are perfect for community-adjacent zones. Additionally, remote monitoring and geofencing capabilities allow safety and asset oversight with minimal manual intervention. The floating-head design adapts to undulating terrain commonly found in medians and interchange slopes. Overall, BigMow supports DOT objectives by reducing labor hours, lowering maintenance costs, minimizing environmental impact, and improving safety and continuity of roadside vegetation management.

Autonomous Electric Commercial Mower (Full Automation)

Link: [John Deere Autonomous 9RX / Commercial Mower](#)

John Deere unveiled a fully electric, stand-on autonomous mower at CES 2025, built upon the company's expertise in turf and agricultural autonomy. Designed for large-scale commercial landscapes such as office parks, solar farms, campus grounds, the mower integrates a 60" rear-discharge deck with triple electric blade motors and a robust drive system powered by a 21.4 kWh battery. It offers zero emissions and significantly reduced noise, enabling quiet operation even during dawn or dusk.

Key Features of the mower include:

- Advanced perception & navigation:
 - Eight cameras (front, rear, left, right) for 360° awareness
 - GPS mapping, odometry, and onboard AI allow operation even in GPS-limited areas
- User-friendly boundary mapping:
 - Operators walk perimeter once, select a mowing pattern, fold platform, and deploy autonomous mode
- Battery & charging:
 - ~4 hours of continuous mowing (up to 10 hours daily)
 - Off-board charging via standard 120 V–240 V outlets; 6–14 hours to full charge
- Safety & reliability:
 - Proven autonomy tech shared with 8R tractors and ADT machines—ensuring robust performance, repeatable operation, and formal safety protocols

State DOTs can effectively integrate the mower into their maintenance operations to manage roadside turf, park-and-ride facilities, and rest area grounds with increased efficiency. The mower’s autonomous functionality enables a single technician to map mowing zones and supervise multiple machines, freeing maintenance crews to focus on higher-risk or more technical tasks such as slope stabilization or infrastructure repairs. Its quiet, fully electric operation allows for mowing in community-adjacent areas like rest stops and median zones with minimal noise disruption, helping reduce travel complaints and avoiding unnecessary lane closures. The intuitive boundary mapping system, which only requires a single walkthrough of the mowing perimeter, enables seamless scheduling and repeatable deployments across expansive DOT-managed landscapes. Additionally, the mower’s zero-emission electric drivetrain and minimal maintenance requirements align with DOT sustainability goals while lowering long-term operational costs.

Graze Autonomous Commercial Mower (Full Automation)

Link: <https://www.grazerobotics.com/product/graze-mower>

The Graze Autonomous Commercial Mower, developed by Graze Robotics, is a fully electric, GPS-guided, AI-enabled mowing system designed for high-efficiency grounds maintenance across expansive public landscapes. Featuring advanced autonomy, solar-assisted charging, and a powerful 40 kWh battery, the Graze mower is optimized for quiet, emission-free, and labor-saving operation, making it an ideal fit for State DOT maintenance of medians, rest areas, park-and-ride lots, and highway-adjacent greenways.

Key features of the system include:

- Fully electric drive system: Powered by a 40 kWh lithium-ion battery with optional solar panel integration, enabling up to 8 hours of continuous runtime. Reduces fuel dependency and supports clean energy goals.
- High mowing capacity: Equipped with a 60" tri-blade rear-discharge deck, the mower can cover up to 13 acres per day, depending on terrain and density. Ideal for large, open green areas managed by DOTs.

- Autonomous navigation & perception: Utilizes a suite of GPS, computer vision, LiDAR, and odometry sensors to execute precise mowing paths, avoid obstacles, and operate safely in dynamic environments.
- Fleet management interface: Includes a centralized dashboard that enables remote monitoring, performance analytics, and zone configuration—allowing a single technician to manage multiple units across DOT facilities.
- Quiet, low-disruption performance: Near-silent operation (<60 dB) permits overnight or early morning mowing in sensitive public areas such as rest zones or commuter corridors.

Operation-wise, the Graze mower maps its environment using GNSS and sensor fusion, executes mowing plans autonomously, and returns to its dock for recharging, which minimizes human intervention and maximizing uptime. Its electric architecture, low ground disturbance, and safety-rated design make it suitable for integration in DOT-controlled infrastructure environments. Use cases include:

- Rest areas, park-and-rides, and welcome centers, where quiet operation and aesthetic consistency are vital
- Interstate medians or shoulders with safe access points for autonomous deployment
- Government campuses or DOT field offices requiring routine vegetation maintenance

The system allows DOTs to pre-map mowing zones and deploy Graze units to perform autonomous, overnight mowing cycles. By monitoring performance through a web dashboard, maintenance crews can reallocate time to higher-skill or safety-critical tasks. The result is a ~50% reduction in mowing costs per acre and a significant reduction in emissions and noise pollution.

Ovis™ 40 RC Mower (Remote Operation)

Link: <https://www.gravelly.com/en-us/power-equipment/brush-mower/ovis/ovis-40-rc-mower>

The Ovis™ 40 RC Mower by Gravelly is a compact, remote-controlled slope mower purpose-built for managing vegetation across steep embankments, roadside shoulders, drainage channels, and hard-to-access terrain. Featuring a low center of gravity and rubber-tracked propulsion, the Ovis 40 RC ensures safe and effective mowing on gradients up to 50 degrees, minimizing manual labor risks. Launched as part of Gravelly's industrial-grade equipment line, the Ovis mower supports precision control and visibility in high-risk mowing environments frequently encountered by state DOTs.

Key features of the system include:

- Remote-Controlled Operation: Operated via a robust handheld controller with a range of up to 300 feet, enabling operators to manage slopes, tight rights-of-way, and roadside environments without physical exposure to hazardous terrain.
- All-Terrain Maneuverability: Dual rubber tracks with low ground pressure support agile movement over uneven surfaces and sensitive areas, including soft shoulders.
- High-Capacity Brush Cutting: Equipped with a 38.5-inch cutting deck and a commercial-grade Hydro-Gear® drive system, the Ovis 40 RC efficiently clears thick brush and tall grass, even in moisture-prone or low-visibility zones.

- Compact and Transportable: Weighing just under 1,900 lbs, the machine is easily trailerable and deployable by a two-person crew—ideal for quick-response maintenance.
- Operator Safety & Compliance: Designed to meet modern workplace safety standards by removing operators from direct exposure to roadside traffic, steep grades, and inclement mowing conditions.

The Ovis 40 RC Mower enables remote mowing of high-slope terrain, especially where traditional tractor-mower units or manual crews are unsuitable or non-compliant with evolving safety standards. Use of the Ovis system significantly reduces crew exposure, increases maintenance cycle efficiency, and aligns with DOT mandates on roadside worker safety, operational uptime, and environmental stewardship in routine and emergency maintenance cycles.

Mammotion LUBA 2 AWD

Link: <https://mammotion.com/pages/luba-2-awd>

The LUBA 2 AWD from Mammotion is a perimeter-wire-free, all-wheel-drive robotic mower built to handle steep slopes and complex lawns with autonomous intelligence. It features AWD enabling up to 80 % slope climbing and obstacle clearance (up to 80 mm), and its adaptive suspension helps it traverse uneven terrain smoothly. UltraSense AI Vision powers object detection and surface differentiation so the mower can distinguish between tall grass (to be cut) and obstacles (to avoid), even under tree cover without relying on antennas or GPS. It also supports automatic edge cutting with precision less than 5 cm, can manage up to 60 mowing zones, and maps areas up to 5,000 m² autonomously. The mower is equipped with a 400 mm dual cutting disc system driven by a 165 W motor, along with a high-capacity lithium battery and Mammotion's iNavi™ positioning system (with RTK backup).

Key features include:

- All-wheel drive for steep terrain: 80 % slope capability, 80 mm obstacle clearance
- Adaptive suspension & obstacle negotiation: Smooth handling over bumps or terrain transitions
- AI vision & sensor-based navigation: Operates under tree cover, distinguishes grass vs. obstacles
- Zero-distance edge cutting: Auto edge trimming to within ~5 cm of walls or boundaries
- Multiple mowing zones & large area mapping: Supports 60 zones, auto maps up to 5,000 m²
- Powerful cutting system: 400 mm dual-cut discs driven by a 165 W motor
- Battery & positioning tech: High-capacity lithium battery, iNavi™ satellite & RTK positioning, no antenna dependency

Greenzie

Link: <https://www.greenzie.com/>

Greenzie provides a software solution that transforms standard commercial mowers into autonomous machines via onboard AI and path-planning algorithms. Its suite of features includes “record & repeat” route copying, virtual no-go zones, teleoperation (remote control override), and real-time monitoring of fleet operations. Compatible with a wide range of mower makes and

models, Greenzie enables fleet operators to deploy autonomous mowing without needing to purchase fully robotic platforms, reducing cost and deployment complexity.

Toro Haven Robotic Mower and Toro GeoLink Solutions Autonomous Fairway Mower (full automation and app control)

Link: <https://smartyard.toro.com/>

https://www.toro.com/en/product/GeoLink-Solutions-Autonomous-Fairway-Mower-Series?srsId=AfmBOorKaEeZfjh2incIrz0OOkOH9_2zFcqxzYpiLbWVGvICMtZXOl0K

The Toro Haven Robotic Mower is a vision-guided, wire-free residential mowing solution that combines intelligent navigation with smart scheduling. Designed to simplify lawn care, Haven uses onboard cameras and AI to map yards without perimeter wires, adapting automatically to lawn zones and growth patterns. Users can manage mowing schedules, zones, and preferences directly through the SmartYard™ app, while built-in obstacle detection ensures safe, autonomous operation. With zone management, customizable patterns, and weather-aware scheduling, Haven delivers a hands-free mowing experience tailored to modern smart-home environments.

The GeoLink Solutions Autonomous Fairway Mower is Toro's advanced automation system tailored for golf course maintenance. Equipped with GPS-based navigation and autonomous mowing technology, it enables precise, repeatable fairway coverage with minimal operator input. GeoLink supports smart path planning, zone definition, and adaptive mowing patterns that optimize turf quality and reduce fuel and labor costs. Built for professional course conditions, it integrates seamlessly with Toro's turf management equipment portfolio, offering superintendents greater efficiency, consistency, and control in maintaining world-class playing surfaces.

Green Line Autonomy – Autonomous Ventrac Compact Tractor with Under Cut Mower (retrofit autonomy, roadside vegetation)

Link: <https://greenlineautonomy.com> | <https://www.ventrac.com>

The Autonomous Ventrac Compact Tractor equipped with the Under Cut under-fence mower is provided by Green Line Autonomy, which retrofits Ventrac commercial tractors with autonomy kits for DOT vegetation management. This platform addresses challenging roadside use cases—such as under-fence mowing, medians, and ditches—through AI-driven navigation, obstacle detection, and safe remote operation. The Under Cut mower attachment enables precise vegetation control under guardrails and fence lines, while the autonomous retrofit reduces the need for manual operators in high-risk roadside environments.

Autonomous Seppi M50 Tracked Slope Mower with Under Cut Mower (steep-slope automation)

Link: <https://greenlineautonomy.com> | <https://www.seppi.com>

The Autonomous Seppi M50 Tracked Slope Mower, integrated with autonomy by Green Line Autonomy, is a rugged tracked platform designed for steep slope vegetation management. Built on Seppi's industrial slope-mowing technology, the system adds autonomous navigation, safety monitoring, and obstacle detection to operate in hazardous, uneven, or wet terrain where traditional compact tractors may be unsuitable. The addition of the Under Cut mower attachment provides effective vegetation control beneath roadside barriers, extending its functionality for DOT right-of-way and utility corridor applications.

Autonomous Crack Sealing

Robotic Crack Sealer (Full Automation)

Link: <https://rmv.llc/robotic-crack-sealer/>

The Robotic Crack Sealer is an autonomous cracking sealing system developed by Robotic Maintenance Vehicles (RMV). It is designed to automate the crack sealing process, improving safety, efficiency, and consistency in roadway repair operations. Key features of the system include an articulated robotic arm equipped with high-resolution vision sensors to detect and classify pavement cracks, a heating and blowing module to prepare the crack surface, and a precision-controlled applicator for sealant delivery. The robotic unit is mounted on a maintenance vehicle and can operate autonomously or under remote supervision. During operation, the system navigates the roadway, identifies crack locations in real time, and executes a multi-step sealing process with minimal human intervention.

Tracer (Full Automation)

Link: <https://pave-robotics.com/>

Pave Robotics, a startup founded in 2024, has developed Tracer, a fully autonomous asphalt crack-sealing robot. Their robots operate 24/7, autonomously detecting, cleaning, and sealing cracks with sub-millimeter precision, significantly outperforming manual crews in both quality and efficiency. Beyond crack sealing, Pave Robotics provides real-time, high-resolution pavement condition data, empowering municipalities and private owners with insights to prioritize maintenance and optimize budgeting. The Tracer system integrates advanced sensors and perception capabilities to automate the entire multi-step sealing process—debris removal, heating, and hot-pour sealant application—minimizing labor costs, reducing road closures, and enhancing worker safety. The machine is at small size, which is not designed for sealing cracks on public roads, but within facilities such as parking lots.

Crackfiller (full automation)

Link: <https://www.techbriefs.com/component/content/article/30332-georgia-tech-crackfiller>

The Crackfiller system, developed by the Georgia Tech Research Institute (GTRI) with funding from the Georgia Department of Transportation, introduces a groundbreaking automated solution for pavement crack detection and sealing. Mounted on a vehicle or trailer and driven at approximately 3 mph, the system employs a stereo camera paired with dual-color LEDs to illuminate the pavement and capture high-resolution images of cracks finer than 1/8". Within 100 milliseconds, onboard algorithms generate a precise “crack map,” guiding high-speed sealant nozzles to apply hot-pour sealant accurately. In tests, the vision-based detection correctly identified over 83% of cracks across more than 100,000 images. This prototype automates what was once a labor-intensive and hazardous task, requiring only a single operator and significantly improving safety, throughput, and consistency in crack sealing operations.

Autonomous Pothole Patching

Python 5000⁺ (Tier 4 Final) (Partial Automation)

Link: <https://www.superiorroads.com/products/5000plus>

The Python 5000+ by SuperiorRoads is a heavy-duty, self-propelled asphalt repair machine optimized for continuous crack sealing and pothole patching using standard hot or cold asphalt mixes. Introduced in 2021 in a signature yellow finish (custom colors available), the Tier 4 Final Cummins-powered Python 5000+ meets stringent North American and European emissions standards and delivers 173 hp with 520 lb-ft of torque—ideal for high-volume maintenance.

Key features of the system include:

- **Continuous sealing capability:** Designed for long cracks and joints, enabling seamless repair operations in a single pass.
- **Single-operator cab:** One person can safely and comfortably drive and operate the machine, significantly reducing labor requirements.
- **All-weather operation:** Effective in diverse conditions with minimal road closures and enhanced worker safety.
- **Large capacity & robust chassis:** Weighing ~28,120 lb (12,760 kg), it supports lengthy repairs across busy road networks.

Operation-wise, the Python 5000+ navigates roadways and autonomously dispenses asphalt mix via heated applicators as it progresses, ensuring precise, long-lasting patches and continuous crack filling. Its user-friendly controls, combined with durable construction and environmental compliance, make it a highly scalable solution for municipalities and contractors seeking efficient, machine-driven pavement maintenance.

Pothole Pro (Partial Automation)

Link: <https://www.jcb.com/en-gb/products/pothole-pro/pothole-pro>

The JCB Pothole Pro is an innovative 3-in-1 municipal road-repair machine designed to mechanize what used to require multiple crews and tools—cutting, cropping, and cleaning potholes with a single ride-on unit. Featuring a 600 mm planer with hydraulic depth, tilt control, and 1.3 m side shift, operators can cut precise potholes from the cab—eliminating manual saws and reducing vibration and safety risks. A 400 mm hydraulic cropper plus a sweeping collector with dust suppression prepare and clean the repair area, gathering debris efficiently for recycling. A typical repair takes just 8 minutes, making it up to four times faster and about half as costly as traditional methods. With a working width of up to 250 m² per day and a travel speed of ~40 km/h, it's designed for rapid relocation and high-volume repairs (700 potholes/month) under live traffic. Awarded for boosting productivity and safety—minimizing labor, shielding crews from manual cutting, and enhancing visibility with 360° cab view—Pothole Pro is already being widely adopted by UK councils and major contractors.

The machine's versatility also allows it to switch out attachments for tasks such as ditching, hedge trimming, and general site maintenance, making it a flexible asset for municipal fleets.

Bergkamp SP5E Spray Injection Pothole Patcher

Link: <https://www.bergkampinc.com/products/sp5>

The Bergkamp SP5E is a next-generation spray injection pothole patcher designed to automate and streamline roadway maintenance operations. Built with safety, efficiency, and sustainability in mind, the SP5E integrates advanced spray technology, telematics, and operator-assist features

to deliver durable pothole repairs with minimal environmental impact. Its elimination of an auxiliary engine further reduces emissions and long-term maintenance costs, aligning with DOT sustainability goals.

Key features of the system include:

- Automated patching process: Equipped with an in-cab control system that manages the four-step spray injection process—blowing out debris, applying tack coat, filling the cavity, and applying top coat.
- Advanced spray boom: Features a two-section spray boom with nozzle oscillation for precise material placement and consistent patch quality.
- Operator safety systems: Includes a boom lane departure system and a 360-degree camera to protect workers and ensure safer operations in live traffic environments.
- Flexible hopper options: Available in single or dual hopper configurations to handle varying job site demands.
- Integrated telematics: NPAV system provides real-time data reporting on patching activity, enabling performance tracking, accountability, and maintenance planning.
- Eco-efficient design: Operates without an auxiliary engine, reducing fuel consumption, emissions, and lifecycle maintenance requirements.

Operationally, the Bergkamp SP5E enables DOT crews to perform faster, safer, and more consistent pothole repairs compared to traditional methods. By combining automation with telematics, the system improves worker safety, extends pavement life, and lowers total cost of ownership. Its integration of sustainability and data-driven reporting makes it a strong fit for modern DOT asset management programs.

Velocity – Spray Injection Patching Technology

Link: <https://velocityroads.co.uk/spray-injection-patching/>

The Velocity spray injection patching machine is a specialized pothole repair vehicle designed to deliver fast, durable, and cost-effective road surface repairs. With its compact 11-ton design and short wheelbase, the system is tailored for use on narrow rural and urban roads where larger patching units cannot easily operate. Its redesigned low-emission engine and streamlined maintenance features align with sustainability goals while ensuring long-lasting performance in demanding roadway conditions.

Key features of the system include:

- Compact vehicle design: An 11-ton platform with a shorter wheelbase engineered to navigate tight, rural, and restricted-access roads.
- Redesigned diesel engine: Powered by a 19-kilowatt diesel engine with improved fuel efficiency and reduced emissions, supporting sustainability objectives.
- Spray injection repair method: Uses high-pressure air to clear the defect, applies emulsion, and injects aggregate for durable, weather-resistant pothole patches.
- Operator-friendly design: Improved ergonomics and simplified daily check processes reduce downtime and enhance ease of operation.
- Durable performance: Produces long-lasting, cost-efficient repairs with less disruption to traffic compared to traditional cut-and-fill patching methods.

Operationally, the Velocity system is particularly effective for counties and municipalities maintaining extensive networks of narrow or rural roads. By combining maneuverability, sustainability-focused engineering, and reliable spray injection repair technology, it enables faster patching cycles, reduced emissions, and lower lifecycle road maintenance costs.

LeeBoy Rosco RA-400 Pothole Patcher

Link: <https://www.leeboy.com/products/ra-400/>

<https://ambroseequipment.com/product/rosco-ra400-patcher/#tab-description>

<https://www.cubexltd.com/listings/6164988-used-2019-leeboy-rosco-ra400-patcher>

The LeeBoy RA-400 is a truck-mounted spray injection system engineered for fast and durable pothole repairs. Its operator-controlled boom arm enables in-cab operation for greater safety, while delivering high-pressure emulsion and aggregate mixtures directly into defects.

Key features include:

- Spray injection repair: High-pressure delivery of emulsion + aggregate mix.
- Operator-controlled boom: Precise application managed from inside the cab.
- Truck-mounted mobility: Enables continuous operation along roadways.
- Safety & efficiency: Reduces crew size and exposure to traffic.

Schwarze Roadpatcher (Chassis Mount)

Link: <https://schwarze.com/en/product-catalog/>

The Schwarze Roadpatcher (Chassis Mount) is a truck-mounted automated spray injection patcher engineered for safe, efficient, and long-lasting pavement repair. Operated entirely from the cab, it performs a four-step process—cleaning, tack coating, aggregate injection with compaction, and dry coating—without the need for hot-mix hauling or external compaction equipment. Designed for year-round operation, the Roadpatcher improves crew safety by eliminating exposure to traffic, reduces equipment requirements, and delivers durable patches that open to traffic immediately.

Key features include:

- Four-step repair: Cleaning, tack coating, aggregate injection & compaction, dry coating.
- In-cab operation: Single-operator joystick control for maximum safety.
- Durable repairs: Produces patches designed to last through heavy traffic and weather.
- Year-round productivity: Heated/insulated emulsion tank ensures cold-weather operation.
- Cost savings: Cuts down on labor, material waste, and equipment needs.

Automated Traffic Control Device Placement and Retrieval

Falcon Automated Cone Laying Machine (full automation)

Link: <https://highwaycare.com/highway-care/falcon-automated-cone-laying-machine>

The Falcon Automated Cone Laying Machine (ACLM), developed by UK-based Highway Care in collaboration with SENN Engineering, represents a pioneering leap in traffic management

automation. The Falcon comes in two models: the Falcon 100, designed for 1 m cones used on major motorways, and the more agile Falcon 75, tailored for 750 mm cones suited to local and rural roads. Entirely controlled from the vehicle cab, the Falcon can deploy and retrieve cones in under 10 seconds with exceptional accuracy—up to 7 cones per minute (drop) and 6 per minute (collect)—eliminating the need for operatives to work dangerously near live traffic. It supports tapered layouts, adjustable spacing (3–100 m), and offers multiple deployment modes, all monitored via in-cab cameras and touchscreen controls. The battery-powered Falcon is lightweight enough for narrower roads yet packs capacity for 240–480 cones per run. Operational since 2021 on the M25 via Balfour Beatty, the Falcon ACLM has significantly improved worker safety, reduced manual handling injuries, and boosted productivity through rapid, consistent cone deployment.

X-Cone (full automation)

Link: <https://x-cone.com/en/>

The **X-Cone** is a fully automated traffic-cone management system engineered by Janschitz GmbH, designed to enhance worker safety and contractor efficiency. Operable entirely from the vehicle's cab via an illuminated touchscreen, X-Cone deploys and retrieves up to **6 cones per minute**, with adjustable spacing from **10 m to open end**. Its multidirectional design enables cone handling on both sides of the vehicle and even against traffic flow—ideal for flexible deployment scenarios. The system mounts easily on trucks or trailers using integrated forklift openings and runs on a 12 V DC supply with backup battery, ensuring reliable performance in temperatures ranging from **–10 °C to +50 °C**. With capacity for up to **221 cones (17 stacks × 13 cones)** on a 480 kg frame, it offers robust loading in a compact footprint. Featuring dual-camera monitoring, automatic warning markers, LED work lights, and remote service capabilities, the X-Cone provides high-visibility, safe, and efficient traffic management—minimizing crew engagement in live traffic while supporting rapid, standardized operations.

Cone Setter CS 3100 (partial automation)

Link: <https://epicsolutions.us/epic-solutions-miscellaneous-product-solutions/ram/cone-setter-cs-3100/>

The Cone Setter CS 3100, developed by EPIC Solutions' Road Automation Machinery (RAM) division, is a life-saving cone deployment unit that mounts to flatbed trucks and automates traffic-cone placement. It eliminates the need for workers to walk alongside moving vehicles. After loading cones into a magazine from inside the truck bed, one operator (plus a driver) can set standard 15-inch base cones (28" or 36" tall) at programmed or manual intervals at speeds up to 15 mph, using a handheld control system. Weighing just 57 lb and easily installed in under two minutes via standard stake-pocket mounts, the CS 3100 runs on 12 V DC (with optional air compressor) and can deploy cones forward or backward from either side of the vehicle. By removing workers from harm's way, it accelerates setup time, reduces labor needs, improves accuracy, and significantly mitigates crash risk during traffic control operations. With its simple, safe, and programmable operation, the Cone Setter CS 3100 offers municipalities and contractors an effective tool for enhancing work zone safety and productivity.

AutoCone 2.0 (full automation)

Link: <https://verdegro.com/traffic/verdegro-autocone-2-0/>

The AutoCone 2.0 is a truck-mounted, fully automated traffic cone deployment and retrieval system from Verdegro Group, designed to drastically improve roadwork safety and efficiency. Installed on any standard 18 ton chassis with air suspension and powered via the vehicle's PTO-driven hydraulic pump, this robust system handles up to 400 standard cones stored in eight rotating columns. The barrel-style storage uses high-resistance steel and aluminum, keeping cones clean and functional. Hydraulic clamps and guiding rails ensure precise cone handling, while independent left/right deployment allows placement directly from the cab with just one operator.

Key highlights of the system include:

- High-capacity storage for urban and motorway applications.
- Hydraulic cone picking & placing chamber, with rain cover and electronic/optical sensors for accurate operation .
- Heavy-duty construction for longevity under varied weather and demanding use.
- Flexible integration: mounts on common truck chassis, available in customizable RAL colors.

Optional Mobitrack integration provides real-time GPS tracking, geo-fencing, location history, and safety alerts through platforms like Google Maps and Waze. In summary, the AutoCone 2.0 delivers a scalable, safe, and efficient solution for automated cone management—enabling faster work-zone setup with minimal manual risk.

Raptor 3M (full automation)

Link: <https://www.roadquake-raptor.com/raptor-3m>

The **RoadQuake RAPTOR 3M** is a front-mounted, automated rumble-strip handling system built by PSS Innovations in partnership with Senn Engineering. It's designed to deploy, retrieve, and realign large **3-meter (approx. 10 ft)** temporary portable rumble strips (TPRS) from inside a work truck's cab, keeping crews completely out of traffic. The RAPTOR 3M stores up to **12 strips** and uses a hydraulic arm with **magnet or vacuum gripper technology** to handle the heavy units efficiently—it takes about **90 seconds to deploy** a three-strip array and **2.5 minutes to retrieve** it. Key features include a forward-facing camera and remote-control interface for precise and safe operation, LED work lights for night work, and a compact overhang that maintains road clearance. Compatibility with 12/24 VDC systems or optional onboard battery packs ensure field flexibility and ease of retrofit. In essence, the RAPTOR 3M offers a scalable, safety-driven solution for high-impact work zones by virtually eliminating manual handling of rumble strips and reducing work-zone risks.

Rumble Hog (full automation)

Link: <https://thehog.com/equipment/grinding-grooving-and-rumbling/rumble-hog.html>

The Rumble Hog is a powerful, truck-mounted 3-in-1 system from The Hog Company that combines grinding, grooving, and rumble strip cutting in a single machine. Designed for high-efficiency pavement surface processing, it operates at speeds up to 5 mph while delivering precision cuts through 1" (2.5 cm) diamond-tipped teeth for maximum durability. The Rumble Hog can create rumble strips, recessed markers, plunge cuts, and custom sinusoidal profiles via its standard computer-controlled profiling package. Optional features, such as a scissor-lift high dump, enhance debris management and operator efficiency. By unifying three traditionally

separate processes into one chassis-mounted platform, the Rumble Hog saves time, reduces mobilization costs, and increases roadway safety during operations.

Key highlights:

- 3-in-1 versatility: Grinds markings, grooves pavement for inlaid striping, and cuts rumble strips.
- Precision profiling: Computer-controlled package supports sinusoidal and custom profiles.
- Durability: 1" diamond-tipped teeth ensure long service life and faster cutting.
- Operational efficiency: Processes at up to 5 mph with optional high-dump debris system.
- Cost savings: Consolidates multiple machines into one unit, reducing labor and mobilization needs.

Autonomous Sweeping

Trombia Free (full automation)

Link: <https://trombia.com/products/trombia-free/>

The Trombia Free is a high-power, electric, fully autonomous street-sweeping system, engineered by Finnish-based Trombia Technologies (a FAUN Group company). Designed for industrial hubs, airports, seaports, parking facilities, and gated municipal districts, it tackles up to 30,000 m² per charge using just ~15 % of the energy that traditional sweepers require. Equipped with 3D LiDAR, GNSS, odometry, and advanced sensor-fusion navigation, Trombia Free operates reliably in all weather and lighting conditions, while maintaining outdoor noise levels under 75 dB and avoiding reliance on water for dust control. Safety is ensured via a PLd-classified system meeting ISO 3691-4 and ISO 13849 standards. Deployments include a service station for autonomous emptying and washing, remote monitoring via 360° cameras, and software-managed scheduling through the “Smooth” cloud platform. Pilot programs launched in 2021 at Helsinki Airport and Espoo (Finland), with commercial scaling underway supported by help-desk services and local maintenance plans. In essence, Trombia Free redefines area-cleaning efficiency, combining robust performance with sustainability and safety in autonomous urban and industrial environments.

RoboSweeper S1 (full automation)

Link: <https://www.weride.ai/products#S1>

WeRide’s RoboSweeper S1 is a cutting-edge Level 4 autonomous electric street sweeper - touted as the world’s first of its kind—designed for fully unmanned operation on sidewalks, bike lanes, parks, greenway paths, and non-motorized roadways. Equipped with 360° sensor coverage (LiDAR and cameras), advanced AI for obstacle avoidance and traffic-sign recognition, and cloud-connected fleet management, the S1 can autonomously start from underground garages, sweep up to 120,000 m² per charge, dump debris at designated sites, refill water, recharge, and return to its depot—all without human intervention. Its compact form factor (approx. 101 in long with brushes), dedicated 400 L water tank, and 240 L waste bin allow for day-and-night operations in all weather, while meeting sanitation demands across 10+ cities including Guangzhou, Beijing, Shenzhen, Dalian, Zhengzhou, and Singapore. By replacing traditional

manual sweeping crews, RoboSweeper S1 enhances safety, reduces labor costs, and promises greener urban cleaning, marking a milestone in autonomous sanitation vehicles.

Urban-Sweeper S2.0 Autonomous (full automation)

Link: <https://www.boschung.com/na-en/product/urban-sweeper-s2-0-autonomous/>

The Boschung Urban-Sweeper S2.0 Autonomous is a fully electric, zero-emission street cleaner engineered for precision and efficiency in urban environments. Powered by a 54.4 kWh lithium-ion battery, it achieves a full work shift on just a 100-minute charge and features a 2 m³ debris hopper weight-optimized at 2.3 t—about 1 ton lighter than comparable models. With a compact 1.15 m width and articulated steering enabling a tight 3.3 m turning radius, it navigates narrow streets and curbs with ease. Operational agility is further enhanced by oscillating suspension, cruise control, and an intuitive joystick and touchscreen control interface.

Equipped with a suite of sensors—LiDAR, cameras, mm-wave radar, and GNSS/INS—the S2.0 offers 360° situational awareness, enabling Level 5 autonomous operation such as autonomous wake-up, navigation, parking, and obstacle avoidance in public spaces. It features safety overrides with manual switch and on-both-sides emergency stops. For data insights and remote management, the system integrates with Boschung’s cloud platform bVision, delivering live diagnostics, fleet coordination, and operational analytics. Internationally deployed in cities like Berlin, Chicago, Shanghai, and Duisburg, the S2.0 underscores Boschung’s mission to provide smart, sustainable, and safe autonomous cleaning solutions for modern municipalities.

Bucher + Enway CityCat 2020ev Autonomous Sweeper (self-driving, remotely monitored)

Link: <https://www.buchermunicipal.com/us/en/news/autonomous-sweeper-0>
<https://www.enway.ai/>

The CityCat 2020ev Autonomous Sweeper, nicknamed “Donner”, is a fully electric compact sweeper from Bucher Municipal, enhanced with ENWAY’s autonomous driving technology. Designed for industrial and municipal sweeping, the system operates at low speeds, executing cleaning routes and schedules that can be remotely set and adjusted via a teleoperation center. Operators monitor status and safety through Bucher Connect, which also provides predictive support and maintenance insights. With a 2 m³ hopper, sweeping and vacuuming functions with water, and ENWAY’s AI-driven autonomy, the CityCat 2020ev delivers efficient, quiet, and zero-emission cleaning for both industrial sites and city environments.

Key features include:

- Fully electric operation: Zero emissions with sweeping, vacuum, and water functions.
- Autonomous navigation: ENWAY’s AI platform enables route execution and remote adjustments.
- Remote monitoring: Teleoperation center oversees routes, safety, and operating status.
- Predictive maintenance: Supported through Bucher Connect digital services.
- Compact but capable: 2 m³ hopper capacity for urban and industrial sweeping tasks.

Autonomous Culvert Inspection

RedZone Robotics Solo (full automation)

Link: <https://redzone.com/our-technology/solo/>

The SOLO Pipeline Inspection Robot, developed by RedZone Robotics, is a compact, fully autonomous crawler purpose-built for inspecting small-diameter sewer and pipeline infrastructure. Sized for 8–12 in (200–300 mm) pipes, SOLO carries dual “panospheric” cameras offering 360° virtual pan-tilt-zoom video resolution, enabling comprehensive internal views without manual camera control. Weighing just enough for single-person deployment, units are launched via manhole in 10–15 minutes, where they autonomously traverse pipes, retracing their path upon end or obstruction—operations enhanced when deployed in “squads” of up to four units to maximize productivity. Compared to traditional CCTV systems, SOLO delivers approximately six times the inspection throughput—up to 4,500 ft per day per crew—while dramatically lowering setup time, traffic management needs, and carbon footprint due to its battery-powered design. The platform automatically produces NASSCO-certified defect reports (PACP/MACP), and data seamlessly integrates with RedZone’s Integrity cloud software for asset management—positioning SOLO as a transformative tool for high-efficiency, data-driven infrastructure inspection.

PIPE-I (remote operation)

Link: <https://www.beca.com/ignite-your-thinking/ignite-your-thinking/november-2024/meet-pipe-i-the-robotic-survey-vehicle-on-a-mission>

The PIPE-i is a six-wheeled autonomous survey robot engineered by Beca in New Zealand, purpose-built to inspect confined, hazardous underground structures—such as culverts, stormwater pipes, and tunnels. Developed from mid-2022 through June 2023 in response to a dangerous culvert inspection, it features a lightweight polycarbonate–carbon fiber 3D-printed body with individually suspended wheels for navigating uneven terrain. PIPE-i is equipped with four 850-lumen LED panels, a pan-tilt camera, LiDAR, and an onboard Leica BLK360 3D scanner that delivers high-resolution point-cloud mapping (680,000 points per second), all controlled via radio link and backed by a Raspberry Pi-based ROS autopilot. Its adjustable height (200–500 mm) enables operations in both shallow and deep environments, with real-time data transmitted for remote monitoring—enhancing safety, accuracy, and efficiency in essential infrastructure surveys. PIPE-i offers potential for further autonomy through future AI/ML integration.

Pearpoint P350 flexitrac Inspection System (remote operation)

Link: https://www.pine-environmental.com/products/pearpoint_p350_flexitrac_inspection_system

The Pearpoint P350 Flexitrac Modular Video Pipe Inspection System, offered by Pine Environmental (distributed by CUES/Pearpoint), is a rugged, highly adaptable crawler-based inspection solution ideal for a wide range of pipeline applications. Its modular design includes an IP53-rated command module with an ultra-bright 8" TFT screen and joystick controls, allowing remote control of both crawler and camera—while optional accessories like a powered elevator enable centered inspections in pipes from 6" to 36". The system supports interchangeable high-

resolution cameras—forward view, pan-and-tilt, and pan-tilt with 10× optical zoom—each equipped with ultra-bright LEDs, and can be fully submerged (IP68 rating to 100 m). Its flexible data features include CF card and USB storage, Bluetooth photo sharing, and PC reporting via FlexiSight™, plus built-in inclinometer and sonde for pipeline profiling. Transportable via van or truck or on-site via ergonomic barrow, P350 Flexitrax balances performance, portability, and durability—making it a comprehensive tool for professional pipeline inspection teams.

Stormer S3000 Pipe Crawler

Link: <https://www.fiberscope.net/pipe-crawler-stormer-s3000/>

The Stormer S3000 Pipe Crawler is a robust, portable inspection robot designed in the UK for sewer, drain, and industrial pipeline assessment. Capable of inspecting pipes from 150 mm to 1000 mm (6"–40") in diameter and lengths up to 820 ft, the S3000 combines a waterproof pan-and-tilt camera with powerful four-wheel drive traction, enabling detailed frontal and lateral inspections even in challenging environments. Its integrated control unit includes a 10.4" TFT monitor, DVR with USB recording and WinCan compatibility functions, all housed in a durable PELI-style case for field portability. The crawler's rugged brass and stainless-steel construction, scratch-proof sapphire lens, and 5-bar waterproofing ensure dependable performance under demanding conditions.

Key capabilities include:

- Wide pipe range: Operates in diameters from 6" to 40" (150–1000 mm).
- Extended reach: Travels up to 820 ft inside pipelines.
- High-quality imaging: Waterproof pan-tilt camera with super-sensitive CMOS sensor and 1100-lumen LED lighting.
- Portable control unit: Integrated DVR, monitor, text overlay, and USB storage in a compact, rugged case.
- Durable design: Brass and stainless-steel crawler body with scratch-resistant sapphire lens, IP68 waterproof to 5 bar.

Flyability Elios 3

Link: <https://www.flyability.com/elios-3>

The Elios 3 from Flyability is a cage-drone designed specifically for safe, high-fidelity inspections and 3D mapping in confined or GPS-denied spaces. Controlled remotely via a tablet interface, it fuses LiDAR and vision-based SLAM (FlyAware™) to stabilize flight, create real-time 3D maps, and maintain situational awareness—even in complete darkness or in cluttered interiors. Its impact-resilient design allows it to flip and recover in midair, reducing crash risk.

Key features include:

- Collision-resilient cage design: Signature protective cage plus motors that allow recovery from flips.
- SLAM-based stabilization & mapping: Combines LiDAR and computer vision to build 3D point clouds on the fly and localize in GPS-denied environments.
- High-quality imaging & lighting: 4K main camera with 180° field of view and a dust-proof, multi-panel lighting system delivering up to 16,000 lumens.

- Flight time & payload options: Up to ~12 min without added payload, ~9 min with LiDAR mapping payload. Modular payload bay supports LiDAR, thermal, and other sensor options.
- Return-to-signal & autonomous fallback: Automatically routes back along the flight path if video or link is lost, enhancing mission safety in challenging environments.
- Robust for real-world conditions: Operates in temperatures from 0 °C to 50 °C; base platform offers splash/dust resistance (IP44 equivalent).

The Hydraulic Inspection Vehicle Explorer (HIVE) Culvert Inspection
<https://www.dot.state.mn.us/research/projects/hive/hive.html>

The HIVE (Hydraulics Inspection Vehicle Explorer) is a low-cost, remote-controlled culvert inspection vehicle designed and built internally by MnDOT District 6. Developed to enhance worker safety and improve inspection efficiency, the HIVE allows crews to examine drainage pipes and culverts without entering confined spaces or relying on expensive contractor services. Built from off-the-shelf parts such as hobby-grade RC components, waterproof cameras, and LED lighting, the HIVE can be assembled and maintained in-house, with each MnDOT district able to build its own unit using shared schematics and parts lists. Rugged enough to traverse debris and wet conditions, the HIVE transmits live video back to operators for structural assessments, blockage detection, and documentation. By shifting inspections away from manual entry, it reduces risk, lowers costs, and enables broader coverage of MnDOT's underground infrastructure.

Key features include:

- Remote-controlled culvert access: Safely inspects confined spaces without human entry.
- Low-cost build: Constructed from readily available RC parts, cameras, and LEDs.
- Replicable design: Plans and parts lists distributed so each MnDOT district can build its own.
- Durable performance: Operates in wet, debris-filled culverts up to hundreds of feet long.
- Safety & efficiency gains: Reduces worker risk while expanding inspection coverage at minimal cost.

Automated Roadway Inspection

LCMS-2 (Full automation)

Link: <https://www.pavemetrics.com/applications/road-inspection/lcms2-en/>

The LCMS-2 by Pavemetrics is a fully automated, high-speed 3D surface profiling and distress detection system designed for precise pavement condition assessment across large highway networks. Integrated into inspection vehicles, the LCMS-2 utilizes dual high-resolution laser line projectors and cameras to capture detailed 3D and 2D data of the road surface at highway speeds (up to 100 km/h). The system is engineered for DOT-grade asset management and predictive maintenance applications.

Key features of the system include:

- 3D Crack & Surface Defect Detection: Accurately detects longitudinal, transverse, and alligator cracks, as well as rutting, potholes, and raveling using real-time 3D texture mapping.
- High-Speed Operation: Captures continuous data at speeds up to 100 km/h (62 mph), minimizing traffic disruption and enabling efficient network-level surveys.
- Automated Data Processing: Integrates with Pavemetrics' software to produce crack maps, IRI, macrotexture (MPD), rut depth, and other condition indices automatically.
- Modular Integration: Can be combined with other Pavemetrics sensors (e.g., Right-of-Way Mapping, Macrotexture, Road Geometry modules) for multi-functional inspections.
- DOT-Approved & Proven: Used by numerous transportation agencies across North America and Europe for network-wide pavement condition evaluations.

In operation, the LCMS-2 scans the pavement using structured light triangulation and synchronized imaging to deliver ultra-precise surface measurements. This enables transportation agencies and contractors to monitor pavement degradation, plan maintenance schedules, and allocate budgets based on objective, automated diagnostics. The system offers a scalable, efficient, and repeatable alternative to manual surveys or video-based methods, supporting modern infrastructure asset management goals.

Greenwood TSD (Traffic Speed Deflectometer) (full automation)

Link: <https://greenwood.dk/road/tsd/>

The Traffic Speed Deflectometer (TSD) by Greenwood Engineering is a cutting-edge rolling wheel deflectometer that continuously measures the structural bearing capacity of pavements at traffic speeds. The 4th-generation Greenwood TSD integrates high-frequency Doppler lasers, inertial sensors, and advanced data fusion to deliver real-time deflection data across both project and network-level pavements. Developed to replace point-based systems like the Falling Weight Deflectometer (FWD), the TSD enables safer, faster, and more cost-effective structural condition assessments.

Key features of the system include:

- Continuous Deflection Measurement: Uses Doppler lasers (250 kHz, dual 11-head systems) mounted between rear twin wheels to measure pavement response in both front and rear of the load axle.
- Visco-elastic Back-Calculation: Calculates e-moduli and strain values with high accuracy to support pavement lifetime and maintenance cost modeling.
- Integrated Structural Indices: Outputs SCITSD (Structural Curvature Index for TSD), SCI300, and full deflection bowls for advanced pavement modeling.
- Modular Sensor Suite: Can be equipped with Ground Penetrating Radar (GPR), surface profilers, surface imaging (SIS), crack detection, and Right-of-Way cameras.
- All-in-One Pass Efficiency: Collects synchronized road bearing capacity, layer thickness, surface distress, and imaging data in a single uninterrupted drive.

Mounted on a custom trailer platform, the Greenwood TSD collects structural and surface data at traffic speed, requiring no lane closures. The system provides consistent outputs across rigid and flexible pavements and has been adopted internationally by agencies like FHWA (USA),

Highways England (UK), and Danish Road Directorate. Data can be visualized through web-based GIS tools, and post-processing software is provided to analyze full deflection curves, SCITSD, and strain predictions—making it ideal for condition forecasting and network maintenance planning.

ROMDAS System (Mobile Mapping & Pavement Data Collection) (Full Automation)

Link: <https://romdas.com/romdas-system.html>

ROMDAS, developed by Data Collection Ltd (a Moog Inc. company), is a modular, highly automated pavement and asset inspection platform designed to retrofit onto standard survey vehicles. It integrates synchronized sensing, imaging, and navigation systems to enable comprehensive condition surveys while driving at highway speeds, eliminating the need for manual triggers or lane closures.

Key features of the system include:

- Fully automated data capture: Core ROMDAS hardware, controlled via ROMDAS DAS software on a vehicle-mounted computer, automatically synchronizes high-resolution GPS/IMU, DMI, cameras, laser profiler, LCMS, and video in real time
- Modular sensor suite: Choose add-ons such as bump integrator, laser crack profiler (LCMS), laser profilometer, transverse profiler logger, right-of-way and pavement-view cameras, and road geometry unit—all collecting data seamlessly
- Automated crack & defect detection: Equipped with LCMS add-on, the system identifies cracks, potholes, rutting, macrotexture (MPD), delamination, and edge drop-offs automatically during the scan
- Mobile mapping & video logging: Offers 360°, pavement-view, and right-of-way video modules that trigger automatically based on distance; paired with DataView and Mobile Mapping software, they enable event coding and GIS layer export
- Road geometry profiling: With dedicated IMU/GNSS geometry unit, ROMDAS computes slope, crossfall, curvature, and super-elevation automatically
- Seamless post-processing: DataFlow from ROMDAS DAS into DataView and Mobile Mapping toolkit provides integrated GIS export (SHP, KML), video/event coding, iRAP compliance, and pavement management outputs

The ROMDAS system operates from the survey vehicle roof or bumpers, automatically acquiring synchronized pavement profiling, imaging, GPS, and geometry metrics during a single highway-speed pass. Post-survey, the operator uses DataView to perform quality checks, video coding, and generate GIS-compatible asset layers. Final deliverables include longitudinal roughness, crack and distress maps, 3D pavement profiles, road geometry, pavement-view imagery, and mobile-mapped assets—supporting network-level asset management with minimal manual effort or disruptions.

Routescene Mobile LiDAR Mapping System (Vantage) (Full Automation)

Link: [Routescene Mobile LiDAR Mapping System](#)

The Routescene Mobile LiDAR Mapping System (also known as Vantage when equipped with the Velodyne HDL-32) is a turnkey, vehicle-mounted LiDAR solution designed for automated, high-speed highway and asset surveys. This fully integrated system combines precision laser

scanning, GNSS/INS positioning, and onboard processing—delivering rich 3D data without manual triggering or additional sensor setups

Key features of the system include:

- Turnkey hardware & software suite: Includes Velodyne HDL-32 LiDAR, survey-grade GNSS/INS, mounting framework, data storage, and LiDARViewer Pro processing tools—ready for immediate deployment.
- High-performance point cloud: Captures up to 1.39 million points per second, with 32 laser channels covering a 41.33° vertical field of view and 100 m range, achieving ±20 mm accuracy.
- Mapping-grade positional accuracy: Post-processed accuracy of 1.5" (39 mm) at 30 m, or 3.4" (87 mm) up to 80 m plumb line.
- Synchronized, vehicle-speed operation: Collects geometry, asset mapping, pavement profiling, and roadside data continuously at highway speeds without manual intervention.
- Integrated QA/QC monitoring: Real-time data quality check via onboard software, ensuring high fidelity before processing.
- Robust and adaptable: Lightweight (~2.4 kg), dual power inputs, and operational from –20 °C to +60 °C; easily frames to vehicle roofs with shock-absorbing mounts

Mounted on any 4WD or SUV, the system operates by simply driving along the target route. It automatically triggers LiDAR scans at set intervals, synchronizes positional data, video, and GNSS/INS, while the QA Monitor software tracks scan integrity in real time. Post-processing with LiDARViewer Pro produces dense 3D point clouds, asset extraction (e.g., kerbs, signage, barriers), digital terrain models, and geometry analytics—ideal for highway maintenance, safety audits, and digital twin creation.

ARRES Eye (full automation)

Link: <https://www.robotiz3d.com/arres-eye/>

ARRES Eye, developed by Robotiz3d, is a patent-pending robotic sensing system designed for automated, high-precision road defect detection. Mountable on existing fleet vehicles (e.g., buses, maintenance vans, bin lorries), it scans single lanes at speeds up to 60 mph, using a 3m field of view. It captures depth and volumetric data, enabling detailed mapping of cracks, potholes, and manhole defects. The system classifies and prioritizes problems by severity and size (L × W × D), compiling actionable insights for maintenance teams—all within a no-upfront-cost “Robot-as-a-Service” model. Notable pilot feedback has come from Hertfordshire County Council, Innovate UK, and Vinci Construction UK, praising its accuracy, cost savings, and potential to improve safety.

APTech EDGE (full automation)

Link: <https://www.appliedpavement.com/the-aptech-edge>

The APTech EDGE is an automated, mobile data-collection system deployed on a vehicle that gathers geolocated pavement and asset condition data at normal traffic speeds—no lane closures or traffic control needed. It creates a comprehensive asset inventory with quality condition data quickly, safely, and efficiently, capturing 100% of the field of view. Designed to minimize public

disruption and improve worker safety, EDGE supports assessments for pavements, curbs, sidewalks, signs, and more, and its georeferenced data integrates seamlessly into GIS databases.

Technical and operational features include

- High-speed data capture: Mounted on a vehicle, EDGE collects pavement condition data—such as surface distress imagery, longitudinal/transverse profiles, and rutting measurements—at normal traffic speeds, eliminating lane closures or disruptions.
- Comprehensive field-of-view: Ensures 100% visual coverage, capturing all assets within view—pavement, curbs, sidewalks, and signage.
- Geolocation precision: Every sensed feature is georeferenced, making integration into GIS systems seamless.

Cyclomedia Traffic Signs & Pavement Striping Condition Assessment

Link: <https://www.cyclomedia.com/us/condition-assessment-traffic-signs-pavement-striping>

The Traffic Signs & Pavement Striping Condition Assessment solution by Cyclomedia is an AI-powered platform that automates roadway asset inventory and condition monitoring at scale. Using vehicle-mounted high-resolution RGB imagery fused with LiDAR-derived intensity data, the system applies advanced machine learning algorithms to detect, classify, and evaluate traffic signs and pavement striping with high accuracy.

Key features of the system include:

- Automated recognition: Identifies and classifies a wide variety of roadway signs, striping, and related assets through computer vision.
- Condition scoring: Assigns detailed ratings (e.g., faded, damaged, missing) to support proactive maintenance and compliance with FHWA retroreflectivity standards.
- LiDAR + imagery fusion: Enhances detection accuracy across diverse weather and lighting conditions.
- Network-wide scalability: Vehicle-mounted deployment enables efficient coverage of municipal or statewide road networks.
- Seamless integration: Outputs georeferenced asset data directly into AMS and GIS platforms for streamlined workflows.
- Operational efficiency: Replaces labor-intensive manual surveys with standardized, digital diagnostics, lowering costs and improving repeatability.
- Operationally, Cyclomedia delivers a scalable, data-driven solution that helps transportation agencies track degradation, ensure visibility, and comply with safety regulations. Its fusion of AI analytics, imagery, and LiDAR supports smarter budgeting and long-term roadway asset management.

Blyncsy Automated Sign Inventory and Condition Assessment

Link: <https://blyncsy.com/solutions/sign-inventory/>

Blyncsy's Automated Sign Inventory and Condition Assessment platform uses AI and crowdsourced dash cam imagery to deliver near real-time monitoring of roadside signage. The system continuously collects visual data from vehicles already on the road, applying computer vision to detect leaning, broken, vandalized, obstructed, or missing signs.

Key features of the system include:

- MUTCD-based classification: Accurately identifies and categorizes traffic signs according to federal standards.
- Condition monitoring: Detects a wide range of defects and triggers real-time alerts for rapid response.
- Crowdsourced data model: Leverages connected dash cam imagery for continuous, large-area coverage without deploying dedicated vehicles.
- Efficiency gains: Reduces reliance on manual inspections, lowering costs and improving speed.
- Scalable digital twin: Provides agencies with an up-to-date, virtual network of roadside assets to support planning and safety management.

Operationally, Blynescy enables transportation agencies to maintain accurate and timely sign inventories while addressing hazards quickly. Its use of crowdsourced imagery and AI-driven analysis represents a modern, cost-effective alternative to traditional field surveys.

NCTech Condition Assessment for Traffic Signs & Pavements

Link: <https://nctechimaging.com/solutions/condition-assessment/>

NCTech's Condition Assessment platform integrates 360° street-level imagery with LiDAR-derived intensity data to automate the monitoring of traffic signs and pavement striping across roadway networks. Designed for vehicle-mounted deployment, the system produces high-density condition datasets that support predictive maintenance and regulatory compliance.

Key features of the system include:

- Integrated scoring: Combines RGB imagery analysis with normalized LiDAR intensity for comprehensive condition scores.
- High-density datasets: Captures rich, georeferenced condition data that reduces the need for field inspections.
- Predictive planning: Provides agencies with objective, quantifiable insights for compliance, risk assessment, and investment prioritization.
- Seamless integration: Condition outputs plug into existing GIS and asset management platforms for streamlined workflows.
- Standardized reliability: Replaces inconsistent manual surveys with uniform, repeatable assessments across large-scale networks.

Operationally, NCTech empowers DOTs and municipalities to detect damaged, faded, or missing signs and striping while generating actionable datasets for asset management. Its scalable, data-rich approach enables better planning, faster interventions, and more effective roadway safety programs.

Ricoh Road Surface Inspection System

Link: https://www.ricoh.com/technology/tech/104_road_surface_monitoring

Ricoh's Road Surface Inspection System uses stereo cameras and AI to automate the evaluation of pavement condition as a standard vehicle drives over roadways. The system estimates crack density, rut depth, and surface flatness (σ) by combining depth data from stereo images and

brightness/contrast analysis—eliminating reliance on specialized trucks. Integrated software then translates these measurements into a Maintenance Control Index (MCI) and visual maps, enabling streamlined decision-making, prioritization of repairs, and efficient record generation.

Key features include:

- Stereo-camera depth sensing: Dual cameras detect 3D surface geometry to measure rutting and flatness.
- AI image analysis: Learns from labeled data to identify cracks and pavement defects automatically.
- Maintenance Control Index (MCI): Combines multiple metrics into a single score for repair prioritization.
- Standard-vehicle retrofit: Can be deployed on non-specialist vehicles to reach smaller, residential roads.
- Workflow automation: From image capture to report generation and mapping, the system minimizes manual processing time.

Appendix C. INDOT Pre-Acceptance Survey Body

This appendix provides the body of the INDOT pre-acceptance survey questionnaire used to collect employee perceptions of AMTs.

Pre-Acceptance Survey Questionnaire on Autonomous Maintenance Technologies

Background: Researchers at Purdue University worked with INDOT to explore solutions addressing challenges in road maintenance activities, including improving worker safety by minimizing exposure to hazardous conditions, improving maintenance efficiency and resource utilization, and keeping up with increasing maintenance demand from added lane miles, aging infrastructure, and a possible future workforce shortage.

Objective of the Survey: The survey gathered feedback from INDOT employees on technology readiness, practicality, safety benefits, productivity improvements, integration potential, and real-world effectiveness of AMTs. Responses were intended to help prioritize deployment and guide decision-making on AMTs suited to INDOT needs.

Technologies under consideration: autonomous crack sealing; autonomous pothole patching; autonomous mowing; autonomous traffic control device setup; autonomous snow plowing; autonomous sweeping; autonomous culvert inspection; and automated roadway inspection.

Duration: 10-15 minutes.

Participation: Voluntary and anonymous. Responses were to be handled with strict confidentiality, with only aggregated data reported.

Contact: Principal Investigator Dr. Yiheng Feng, Civil and Construction Engineering, Purdue University, feng333@purdue.edu; Data Collector Ajuna John, Civil and Construction Engineering, Purdue University, john60@purdue.edu.

Study Title: Exploring Autonomous Maintenance Technologies (AMTs) Pre-acceptance Survey.
IRB NUMBER: IRB-2025-00000066.

Section 1: Background Information

Please indicate your role in INDOT: Safety Director; Crew Leader; Maintenance Worker; Other (please specify).

How many years of experience do you have in roadway maintenance and operations? <5 years; 5-10 years; 10-20 years; 20+ years.

Section 2: General Perceptions of AMTs

How familiar are you with automated/autonomous maintenance technologies? Very familiar; Somewhat familiar; Not familiar.

Section 3: Technology-Specific Evaluation

Instructions: For each technology, respondents watched an example video and provided feedback using the Likert scale and ranking/open-ended items below.

Response scale for technology-specific agreement items: Strongly Agree (1), Agree (2), Neither agree nor disagree (3), Disagree (4), Strongly disagree (5).

1. Autonomous crack sealing (identifying and filling cracks in pavement)

Autonomous crack sealing systems use robotic arms, sensors, and vision technology to detect and fill pavement cracks with minimal human intervention. These systems improve sealing consistency and reduce worker exposure to traffic.

Example video: <https://www.youtube.com/watch?v=HbViqUjPpEQ>

Agreement statements:

1. This equipment would improve safety for operators and road users.
2. This technology could enhance productivity compared to current methods.
3. Minimized Traffic Disruption: Automated systems can work during off-peak hours, reducing the impact on traffic flow.
4. The system provides improved accuracy, ensuring precise application of sealant, minimizing waste, and producing consistent repairs.
5. The system is practical for use in Indiana's weather and road conditions.
6. Integration with current INDOT equipment and operations would be feasible.
7. I would support adopting this technology in my district.

Open-ended benefit question: Are there any additional benefits? Please specify.

Ranked risk question: What potential drawbacks or risks do you foresee in adopting autonomous crack sealing? Please rank the following options by dragging.

1. High Costs: The equipment and technology required for automation can be expensive to acquire and implement.
2. Complex Maintenance: Maintaining and repairing autonomous systems requires specialized knowledge, increasing operational complexity.
3. Limited Flexibility: Autonomous systems may struggle with non-standard road conditions or unexpected obstacles that require human judgment.
4. Technological Dependence: Reliance on advanced technology such as GPS and sensors can lead to downtime if technical issues or software malfunctions occur and/or downgraded performance under adversarial environments (e.g., poor visibility, heavy snowfall).
5. Skill Gaps: Operators may need additional training to manage and troubleshoot autonomous systems effectively, which can be a barrier in some regions.

Open-ended drawback question: Are there any additional drawbacks? Please specify.

Ranked barrier question: What are your main concerns or barriers regarding the adoption of autonomous crack sealing? Please rank the following options by dragging.

1. Legislation/Policy-related issues
2. Technology-related issues
3. End-user acceptance
4. Difficult to implement/incorporate into existing practice

Open-ended barrier question: Are there any additional concerns or barriers? Please specify.

Training/support question: What additional training, resources, or support would be needed for successful integration?

Recommendation question: Do you have any recommendations for adopting this technology?

2. Autonomous pothole patching (automatically detecting and repairing potholes)

Autonomous pothole patching machines automate the process of cleaning, filling, and compacting potholes using robotic tools or spray injection methods. They improve work zone safety by reducing field crew presence on roadways and enabling faster, more uniform pavement repairs.

Example video: <https://www.youtube.com/watch?v=2qWC-D139ps>

Agreement statements:

1. This equipment would improve safety for operators and road users.
2. This technology could enhance productivity compared to current methods.
3. Minimized Traffic Disruption: Automated systems can work during off-peak hours, reducing the impact on traffic flow.
4. Enhanced Accuracy: Precise detection and repair of potholes, ensuring longer-lasting fixes.
5. The system is practical for use in Indiana's weather and road conditions.
6. Integration with current INDOT equipment and operations would be feasible.
7. I would support adopting this technology in my district.

Open-ended benefit question: Are there any additional benefits? Please specify.

Ranked risk question: What potential drawbacks or risks do you foresee in adopting autonomous pothole patching? Please rank the following options by dragging.

1. High Costs: The equipment and technology required for automation can be expensive to acquire and implement.
2. Complex Maintenance: Maintaining and repairing autonomous systems requires specialized knowledge, increasing operational complexity.
3. Limited Flexibility: Autonomous systems may struggle with non-standard road conditions or unexpected obstacles that require human judgment.

4. Technological Dependence: Reliance on advanced technology such as GPS and sensors can lead to downtime if technical issues or software malfunctions occur and/or downgraded performance under adversarial environments (e.g., poor visibility, heavy snowfall).
5. Skill Gaps: Operators may need additional training to manage and troubleshoot autonomous systems effectively, which can be a barrier in some regions.

Open-ended drawback question: Are there any additional drawbacks? Please specify.

Ranked barrier question: What are your main concerns or barriers regarding the adoption of autonomous pothole patching? Please rank the following options by dragging.

1. Legislation/Policy-related issues
2. Technology-related issues
3. End-user acceptance
4. Difficult to implement/incorporate into existing practice

Open-ended barrier question: Are there any additional concerns or barriers? Please specify.

Training/support question: What additional training, resources, or support would be needed for successful integration?

Recommendation question: Do you have any recommendations for adopting this technology?

3. Autonomous mowing (automatically maintaining grassy areas along roadways or around facilities)

Autonomous mowing systems use GPS guidance and sensors to perform vegetation control along roadsides, medians, and rights-of-way without direct operator control.

Example video: <https://www.youtube.com/watch?v=uz6PPtHcJhc>

Agreement statements:

1. This equipment would improve safety for operators and road users.
2. This technology could enhance productivity compared to current methods.
3. Provides uniform mowing and maintenance, ensuring an even cut across the entire area.
4. The system is practical for use in Indiana's weather and road conditions.
5. Integration with current INDOT equipment and operations would be feasible.
6. I would support adopting this technology in my district.

Open-ended benefit question: Are there any additional benefits? Please specify.

Ranked risk question: What potential drawbacks or risks do you foresee in adopting autonomous mowing? Please rank the following options by dragging.

1. High Costs: The equipment and technology required for automation can be expensive to acquire and implement.
2. Complex Maintenance: Maintaining and repairing autonomous systems requires specialized knowledge, increasing operational complexity.
3. Limited Flexibility: Autonomous systems may struggle with non-standard road conditions or unexpected obstacles that require human judgment.
4. Technological Dependence: Reliance on advanced technology such as GPS and sensors can lead to downtime if technical issues or software malfunctions occur and/or downgraded performance under adversarial environments (e.g., poor visibility, heavy snowfall).
5. Skill Gaps: Operators may need additional training to manage and troubleshoot autonomous systems effectively, which can be a barrier in some regions.

Open-ended drawback question: Are there any additional drawbacks? Please specify.

Ranked barrier question: What are your main concerns or barriers regarding the adoption of autonomous mowing? Please rank the following options by dragging.

1. Legislation/Policy-related issues
2. Technology-related issues
3. End-user acceptance
4. Difficult to implement/incorporate into existing practice

Open-ended barrier question: Are there any additional concerns or barriers? Please specify.

Training/support question: What additional training, resources, or support would be needed for successful integration?

Recommendation question: Do you have any recommendations for adopting this technology?

4. Autonomous traffic control device setup (automating the placement and/or removal of traffic control devices)

These systems automate the deployment and retrieval of traffic control devices such as cones, barriers, and rumble strips for temporary work zones. By removing workers from live traffic lanes, they significantly improve work zone safety.

Example video: <https://www.youtube.com/watch?v=j29KmtL5s4I>

Agreement statements:

1. This equipment would improve safety for operators and road users.
2. This technology could enhance productivity compared to current methods.
3. Minimized Traffic Disruption: Automated systems can work during off-peak hours, reducing the impact on traffic flow.
4. Consistency: Ensures cones and barriers are placed accurately and consistently, improving overall traffic management and safety.
5. The system is practical for use in Indiana's weather and road conditions.

6. Integration with current INDOT equipment and operations would be feasible.
7. I would support adopting this technology in my district.

Open-ended benefit question: Are there any additional benefits? Please specify.

Ranked risk question: What potential drawbacks or risks do you foresee in adopting autonomous traffic control device setup? Please rank the following options by dragging.

1. High Costs: The equipment and technology required for automation can be expensive to acquire and implement.
2. Complex Maintenance: Maintaining and repairing autonomous systems requires specialized knowledge, increasing operational complexity.
3. Limited Flexibility: Autonomous systems may struggle with non-standard road conditions or unexpected obstacles that require human judgment.
4. Technological Dependence: Reliance on advanced technology such as GPS and sensors can lead to downtime if technical issues or software malfunctions occur and/or downgraded performance under adversarial environments (e.g., poor visibility, heavy snowfall).
5. Skill Gaps: Operators may need additional training to manage and troubleshoot autonomous systems effectively, which can be a barrier in some regions.

Open-ended drawback question: Are there any additional drawbacks? Please specify.

Ranked barrier question: What are your main concerns or barriers regarding the adoption of autonomous traffic control device setup? Please rank the following options by dragging.

1. Legislation/Policy-related issues
2. Technology-related issues
3. End-user acceptance
4. Difficult to implement/incorporate into existing practice

Open-ended barrier question: Are there any additional concerns or barriers? Please specify.

Training/support question: What additional training, resources, or support would be needed for successful integration?

Recommendation question: Do you have any recommendations for adopting this technology?

5. Autonomous sweeping (cleaning road surfaces by removing debris)

Autonomous street sweeping vehicles clean roadways and paved areas using automated navigation and debris collection systems. They support continuous operations in urban areas.

Example video: <https://www.youtube.com/watch?v=i70VVqE5Qi0>

Agreement statements:

1. This equipment would improve safety for operators and road users.
2. This technology could enhance productivity compared to current methods.
3. Consistent Results: Ensures uniform and thorough cleaning of roadways, improving overall cleanliness and maintenance.
4. Minimized Traffic Disruption: Autonomous sweepers can work during off-peak hours or while traffic continues, reducing the impact on road users.
5. The system is practical for use in Indiana's weather and road conditions.
6. Integration with current INDOT equipment and operations would be feasible.
7. I would support adopting this technology in my district.

Open-ended benefit question: Are there any additional benefits? Please specify.

Ranked risk question: What potential drawbacks or risks do you foresee in adopting autonomous sweeping? Please rank the following options by dragging.

1. High Costs: The equipment and technology required for automation can be expensive to acquire and implement.
2. Complex Maintenance: Maintaining and repairing autonomous systems requires specialized knowledge, increasing operational complexity.
3. Limited Flexibility: Autonomous systems may struggle with non-standard road conditions or unexpected obstacles that require human judgment.
4. Technological Dependence: Reliance on advanced technology such as GPS and sensors can lead to downtime if technical issues or software malfunctions occur and/or downgraded performance under adversarial environments (e.g., poor visibility, heavy snowfall).
5. Skill Gaps: Operators may need additional training to manage and troubleshoot autonomous systems effectively, which can be a barrier in some regions.

Open-ended drawback question: Are there any additional drawbacks? Please specify.

Ranked barrier question: What are your main concerns or barriers regarding the adoption of autonomous sweeping? Please rank the following options by dragging.

1. Legislation/Policy-related issues
2. Technology-related issues
3. End-user acceptance
4. Difficult to implement/incorporate into existing practice

Open-ended barrier question: Are there any additional concerns or barriers? Please specify.

Training/support question: What additional training, resources, or support would be needed for successful integration?

Recommendation question: Do you have any recommendations for adopting this technology?

6. Automated roadway inspection (using autonomous systems, such as drones or robots, to perform inspections of infrastructure, identifying defects or areas needing repair)

These systems use high-speed imaging, LiDAR, and machine learning to assess pavement, signs, guardrails, and roadside assets while traveling at highway speeds. Automated inspection improves data accuracy and supports predictive maintenance planning.

Example video: <https://www.youtube.com/watch?v=q1zKiC8eIIA>

Agreement statements:

1. This equipment would improve safety for operators and road users.
2. This technology could enhance productivity compared to current methods.
3. Improved Accuracy: Provides high-resolution imagery and consistent data, leading to more precise identification of defects and issues.
4. Timely Problem Detection: Enables early detection of potential problems, allowing for prompt maintenance and reducing the risk of severe damage.
5. The system is practical for use in Indiana's weather and road conditions.
6. Integration with current INDOT equipment and operations would be feasible.
7. I would support adopting this technology in my district.

Open-ended benefit question: Are there any additional benefits? Please specify.

Ranked risk question: What potential drawbacks or risks do you foresee in adopting autonomous roadway inspection? Please rank the following options by dragging.

1. High Costs: The equipment and technology required for automation can be expensive to acquire and implement.
2. Complex Maintenance: Maintaining and repairing autonomous systems requires specialized knowledge, increasing operational complexity.
3. Limited Flexibility: Autonomous systems may struggle with non-standard road conditions or unexpected obstacles that require human judgment.
4. Technological Dependence: Reliance on advanced technology such as GPS and sensors can lead to downtime if technical issues or software malfunctions occur and/or downgraded performance under adversarial environments (e.g., poor visibility, heavy snowfall).
5. Skill Gaps: Operators may need additional training to manage and troubleshoot autonomous systems effectively, which can be a barrier in some regions.

Open-ended drawback question: Are there any additional drawbacks? Please specify.

Ranked barrier question: What are your main concerns or barriers regarding the adoption of autonomous roadway inspection? Please rank the following options by dragging.

1. Legislation/Policy-related issues
2. Technology-related issues
3. End-user acceptance

4. Difficult to implement/incorporate into existing practice

Open-ended barrier question: Are there any additional concerns or barriers? Please specify.

Training/support question: What additional training, resources, or support would be needed for successful integration?

Recommendation question: Do you have any recommendations for adopting this technology?

7. Autonomous snow plowing (utilizing self-driving technology to address snow/ice on roadways, facilities, parking lots, etc., without human intervention)

Autonomous snow plows use GPS navigation, sensor fusion, and obstacle detection to clear snow from roads and parking areas with little or no onboard operator control.

Example video: <https://www.youtube.com/watch?v=hImUhgXxX20>

Agreement statements:

1. This equipment would improve safety for operators and road users.
2. This technology could enhance productivity compared to current methods.
3. Improved Coverage: Enables snow removal in hard-to-reach or dangerous areas where it might be challenging or risky for human drivers to operate.
4. Scalability and Flexibility: Allows for quick deployment of multiple autonomous units across various locations, providing flexibility in response to different snow events and conditions.
5. The system is practical for use in Indiana's weather and road conditions.
6. Integration with current INDOT equipment and operations would be feasible.
7. I would support adopting this technology in my district.

Open-ended benefit question: Are there any additional benefits? Please specify.

Ranked risk question: What potential drawbacks or risks do you foresee in adopting autonomous snow plowing? Please rank the following options by dragging.

1. High Costs: The equipment and technology required for automation can be expensive to acquire and implement.
2. Complex Maintenance: Maintaining and repairing autonomous systems requires specialized knowledge, increasing operational complexity.
3. Limited Flexibility: Autonomous systems may struggle with non-standard road conditions or unexpected obstacles that require human judgment.
4. Technological Dependence: Reliance on advanced technology such as GPS and sensors can lead to downtime if technical issues or software malfunctions occur and/or downgraded performance under adversarial environments (e.g., poor visibility, heavy snowfall).
5. Skill Gaps: Operators may need additional training to manage and troubleshoot autonomous systems effectively, which can be a barrier in some regions.

Open-ended drawback question: Are there any additional drawbacks? Please specify.

Ranked barrier question: What are your main concerns or barriers regarding the adoption of autonomous snow plowing? Please rank the following options by dragging.

1. Legislation/Policy-related issues
2. Technology-related issues
3. End-user acceptance
4. Difficult to implement/incorporate into existing practice

Open-ended barrier question: Are there any additional concerns or barriers? Please specify.

Training/support question: What additional training, resources, or support would be needed for successful integration?

Recommendation question: Do you have any recommendations for adopting this technology?

8. Autonomous culvert inspection (using autonomous robots or drones to inspect culverts, identifying blockages or structural issues)

Autonomous culvert inspection robots are remotely operated or self-guided devices designed to inspect drainage pipes and culverts using onboard cameras and sensors. They reduce the need for confined space entry and improve inspection coverage under unsafe or inaccessible conditions.

Example video: <https://www.youtube.com/watch?v=H4WbI6l2sts>

Agreement statements:

1. This equipment would improve safety for operators and road users.
2. This technology could enhance productivity compared to current methods.
3. Improved Accuracy: Provides detailed and consistent data on culvert conditions, improving diagnostic accuracy.
4. Early Problem Detection: Identifies issues such as blockages or structural damage early, enabling timely maintenance and preventing major repairs.
5. The system is practical for use in Indiana's weather and road conditions.
6. Integration with current INDOT equipment and operations would be feasible.
7. I would support adopting this technology in my district.

Open-ended benefit question: Are there any additional benefits? Please specify.

Ranked risk question: What potential drawbacks or risks do you foresee in adopting autonomous culvert inspection? Please rank the following options by dragging.

1. High Costs: The equipment and technology required for automation can be expensive to acquire and implement.
2. Complex Maintenance: Maintaining and repairing autonomous systems requires specialized knowledge, increasing operational complexity.

3. Limited Flexibility: Autonomous systems may struggle with non-standard road conditions or unexpected obstacles that require human judgment.
4. Technological Dependence: Reliance on advanced technology such as GPS and sensors can lead to downtime if technical issues or software malfunctions occur and/or downgraded performance under adversarial environments (e.g., poor visibility, heavy snowfall).
5. Skill Gaps: Operators may need additional training to manage and troubleshoot autonomous systems effectively, which can be a barrier in some regions.

Open-ended drawback question: Are there any additional drawbacks? Please specify.

Ranked barrier question: What are your main concerns or barriers regarding the adoption of autonomous culvert inspection? Please rank the following options by dragging.

1. Legislation/Policy-related issues
2. Technology-related issues
3. End-user acceptance
4. Difficult to implement/incorporate into existing practice

Open-ended barrier question: Are there any additional concerns or barriers? Please specify.

Training/support question: What additional training, resources, or support would be needed for successful integration?

Recommendation question: Do you have any recommendations for adopting this technology?

Section 4: Overall Questions

Which AMT(s) do you believe would be most beneficial for INDOT to adopt, and why?

In general, how important do you think AMTs will be for future INDOT operations? Very important; Somewhat important; Not important.

Overall, how supportive are you of INDOT adopting automated maintenance technologies? Very supportive; Somewhat supportive; Neutral; Not supportive.

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1 — evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at docs.lib.purdue.edu/jtrp/.

Further information about JTRP and its current research program is available at engineering.purdue.edu/JTRP.

About This Report

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