A New Pavement Marking Automation Scale

A FRAMEWORK FOR UNDERSTANDING THE EVOLUTION, CURRENT STATE, AND RESPONSIBLE ADVANCEMENT OF AUTOMATION IN PAVEMENT MARKING OPERATIONS.

Why Pavement Marking Automation Matters

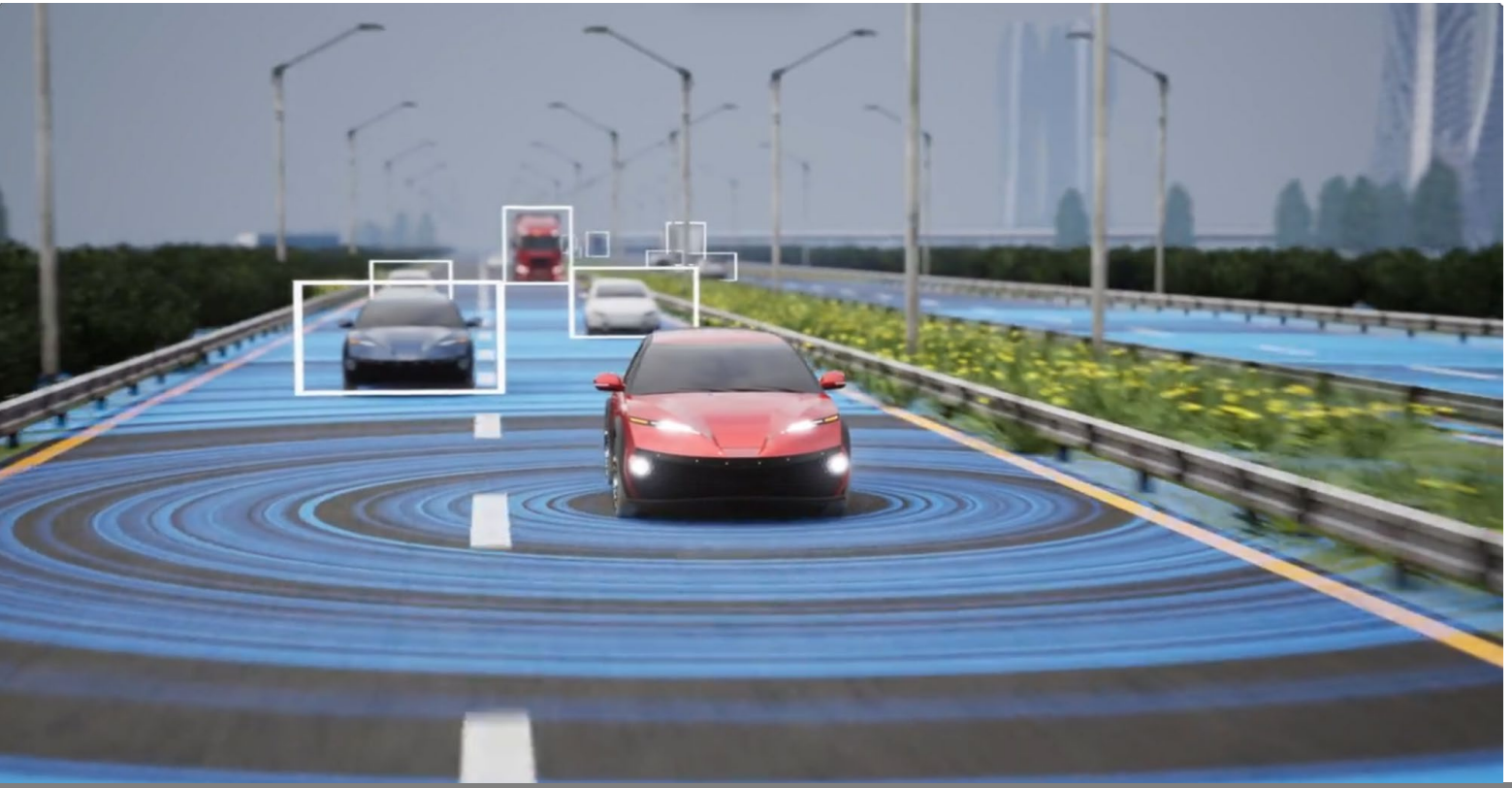
Automation in pavement marking is driven first by safety, followed by compliance and efficiency in a high-risk work environment.

- Accuracy and compliance
- Worker exposure reduction
- Operational consistency

SAE Vehicle Automation Scale as a Reference

- Shared language
- Clear responsibility
- Risk communication

The SAE automation scale provides a model for how complex technologies can be described consistently across industry, regulation, and research.



SAE **J3016** LEVELS OF DRIVING AUTOMATION

Level 0: No Automation	**Human Role:** The human driver is fully responsible for all driving tasks. **Features:** Warnings and momentary assistance. ***Examples:*** *Automatic emergency braking, blind spot warning, lane departure warning.*
Level 1: Driver Assistance	**Human Role:** The human driver performs all remaining aspects of the dynamic driving task. **Features:** Steering OR brake/acceleration support to the driver. ***Examples:*** *Automatic emergency braking, blind spot warning, lane departure warning.*
Level 2: Partial Automation	**Human Role:** The human driver must remain engaged and monitor the driving environment. **Features:** Steering AND brake/acceleration support to the driver. ***Examples:*** *Lane centering AND adaptive cruise control at the same time.*
Level 3: Conditional Automation	**Human Role:** The human driver must be ready to take over when requested. **Features:** Can drive the vehicle under limited conditions. ***Examples:*** *Traffic jam chauffeur.*
Level 4: High Automation	**Human Role:** The human driver can take over if they choose. **Features:** Can drive the vehicle under limited conditions. ***Examples:*** *Local driverless taxis and pedals/steering wheels may or may not be installed.*
Level 5: Full Automation	**Human Role:** No human intervention is required. **Features:** Can drive the vehicle under all conditions. ***Examples:*** *Local driverless taxis and pedals/steering wheels may or may not be installed.*

A Familiar Reference: The SAE Vehicle Automation Scale

Why a Pavement Marking Automation Scale Is Needed

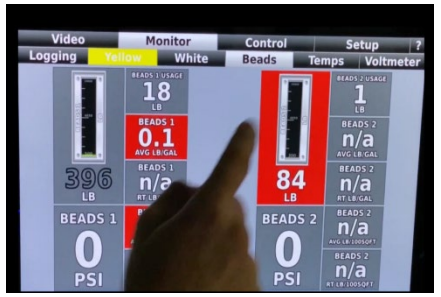
As pavement marking automation accelerates, a shared framework is needed to align expectations and guide responsible deployment.

- Rapid technology advancement
- Increasing automation claims
- Lack of common definitions

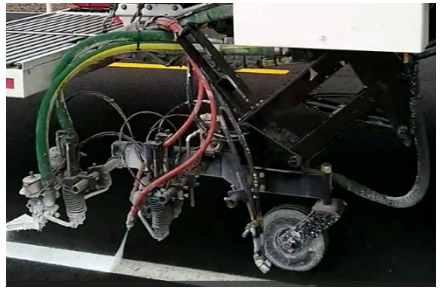
Pavement Marking Application: Core Functional Elements

Automation advances differently across the core functions of pavement marking application, influencing how systems progress along the automation scale.

•Vehicle operation



•Material management



•Gun & carriage control

•Layout and patterning

The Role of Layout in Pavement Marking Automation

Layout represents the largest share of labor and worker exposure, making it inseparable from meaningful automation.

- Majority of labor
- Majority of exposure
- Foundation for accuracy

Pavement Marking Application Automation Levels (0–5)

- Manual to automated
- Equipment capability changes
- Operator role evolves

The automation scale describes increasing system capability and changing operator responsibility from Level 0 through Level 5.

Pavement Marking Automation Scale

Function to Scale Matrix

Automation Level	Vehicle Operation	Material Management	Gun & Carriage Control	Layout	Data Collection
Level 0 Manual Operation	○ Fully manual	○ Manual loading & monitoring	○ Manual selection & activation	○ Manual (string, chalk)	—
Level 1 Operator Assist	○ Human-driven	◐ Basic monitoring	◐ Basic skip timing	○ Manual w/ guides	—
Level 2 Semi-Automated Application	○ Human-driven	● Auto logging & alerts	◐ Advanced timing & positioning	◐ Digital references / lasers	◐ Location & material logging
Level 3 Conditional Automation	○ Human-driven	● Automated monitoring	● AI-driven selection & activation	● GPS/RTK & AI-assisted layout	● Marking location, color, pattern
Level 4 High Automation	○ Human-driven	● Fully automated	● Fully automated carriage	● Project-file & surface-based layout	● Integrated as-built datasets
Level 5 Full Automation	● Autonomous (defined zones)	● Autonomous	● Autonomous	● Fully integrated	● Autonomous data generation

Legend
○ = Manual / Human controlled
◐ = Assisted / Partially automated
● = Highly automated
— = Not applicable / intentionally excluded

How Operator Roles Change with Automation

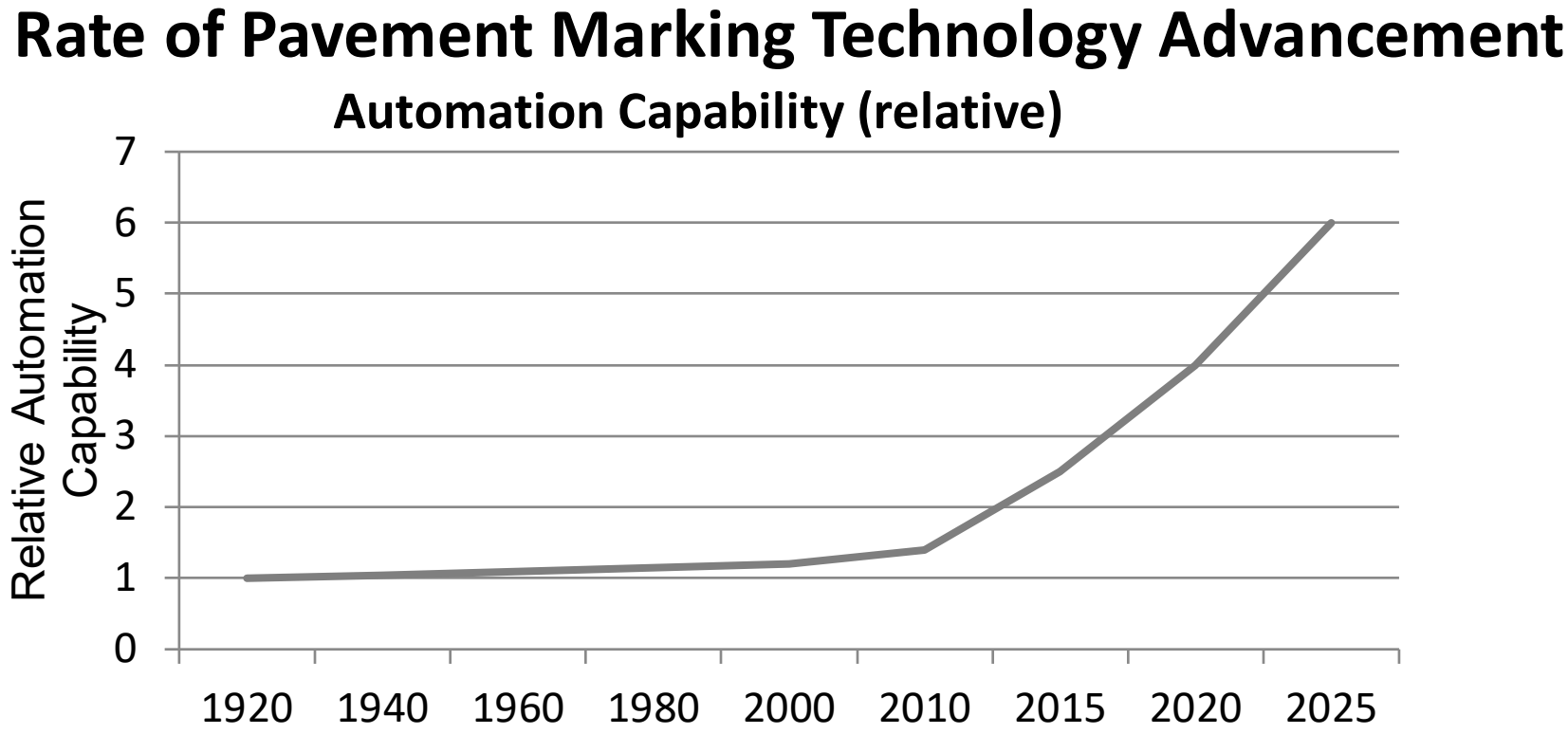
Automation shifts how operators interact with systems, but responsibility remains human at every level.

- Control → supervision
- Decision authority remains
- Accountability unchanged

Operator Responsibility Across Automation Levels

Automation Progress: From Incremental to Accelerated

After decades of incremental change, pavement marking automation has recently entered a period of rapid acceleration.

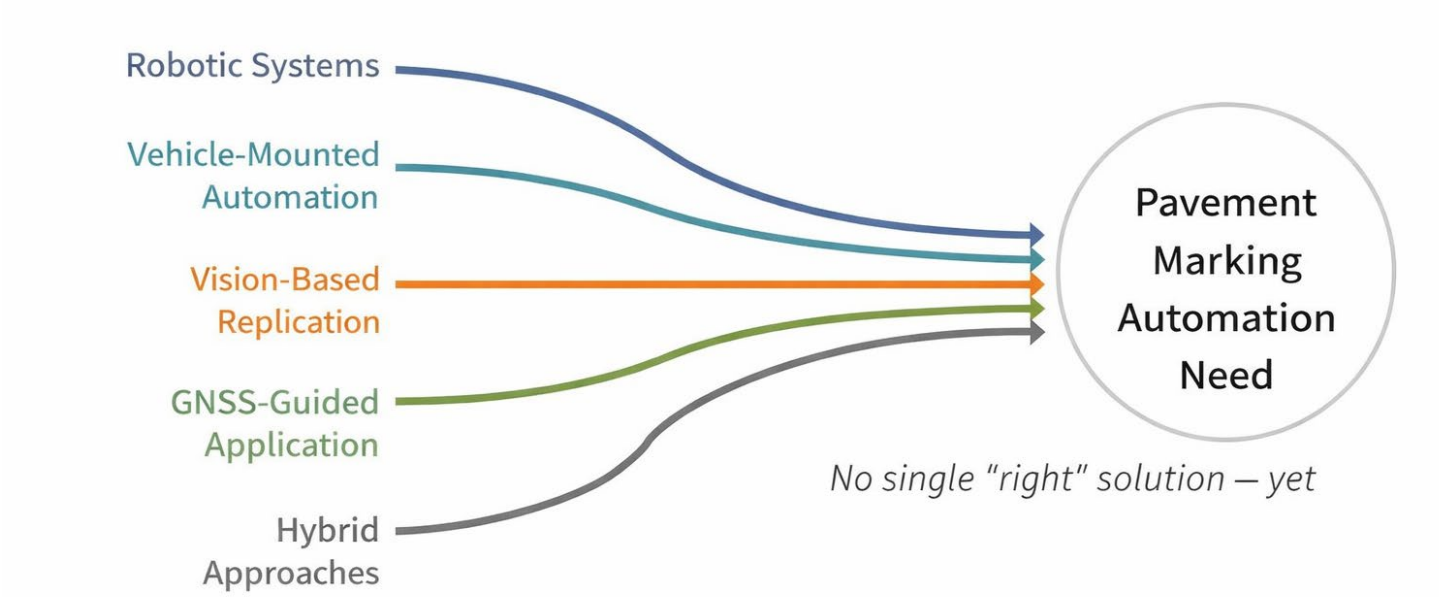


Conceptual illustration of long-term incremental progress followed by recent rapid acceleration

Current Industry Responses to Automation Challenges

Different technologies are advancing along different points of the pavement marking automation scale.

- Multiple automation paths
- Parallel development
- Shared challenges

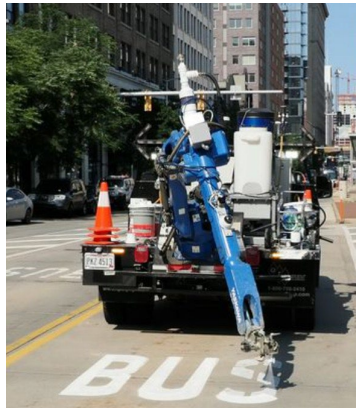


Approaches Map to Different Levels on the Pavement Marking Automation *Scale*

Examples of Automation Approaches in Use Today

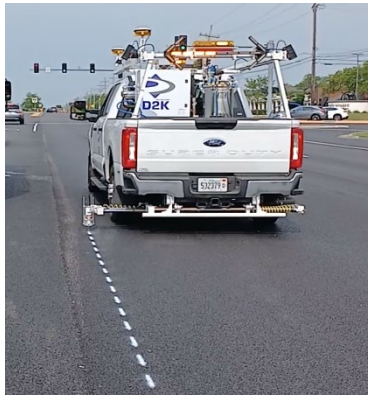
Robotic systems, vehicle-mounted automation, and vision-assisted technologies illustrate how automation is being implemented across the scale.

•Tiny Surveyor Robot
•10-Lines Robotic Striper



•Road Printz Electra

•Traqnology UTV GPS striping



•LifeMark-100 Vehicle Mount Auto Layout

•LifeMark-400 Auto Restripe Assist

Barriers to Advancing Pavement Marking Automation

As with any advancing technology, real-world barriers influence how quickly higher levels of automation can be achieved safely.

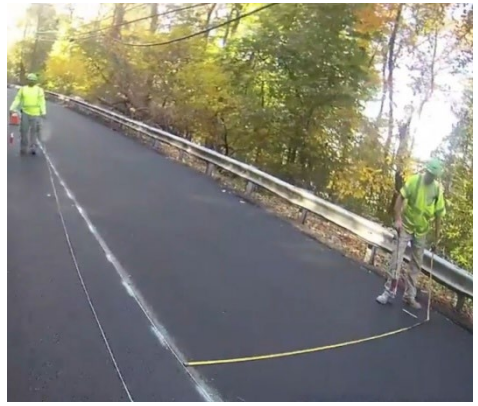
Barrier 1: Lack of Precision Roadway Data

Automated pavement marking requires precision data that exceeds the accuracy of most existing roadway datasets.

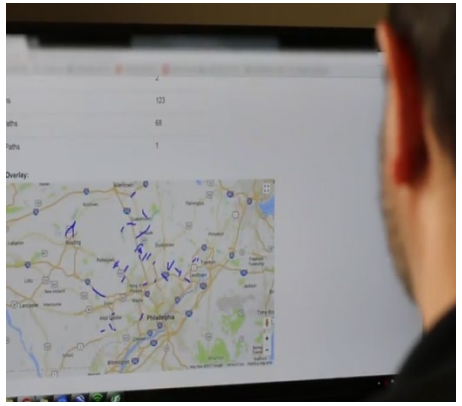
- Centimeter accuracy required
- Most roads not digitized
- As-built ≠ design data
- GIS data insufficient

Addressing the Precision Data Gap

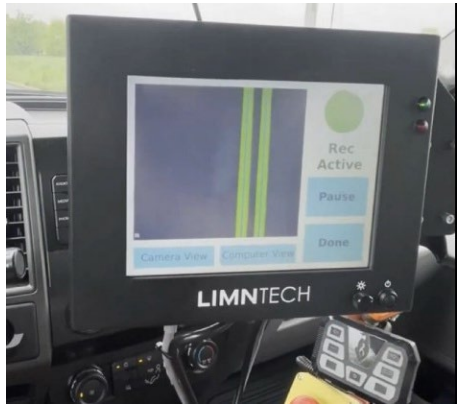
Current approaches to data and layout automation address the lack of precision roadway data by generating, validating, or adapting information during operations, enabling advancement within mid-level automation categories.



•Manual field layout and survey



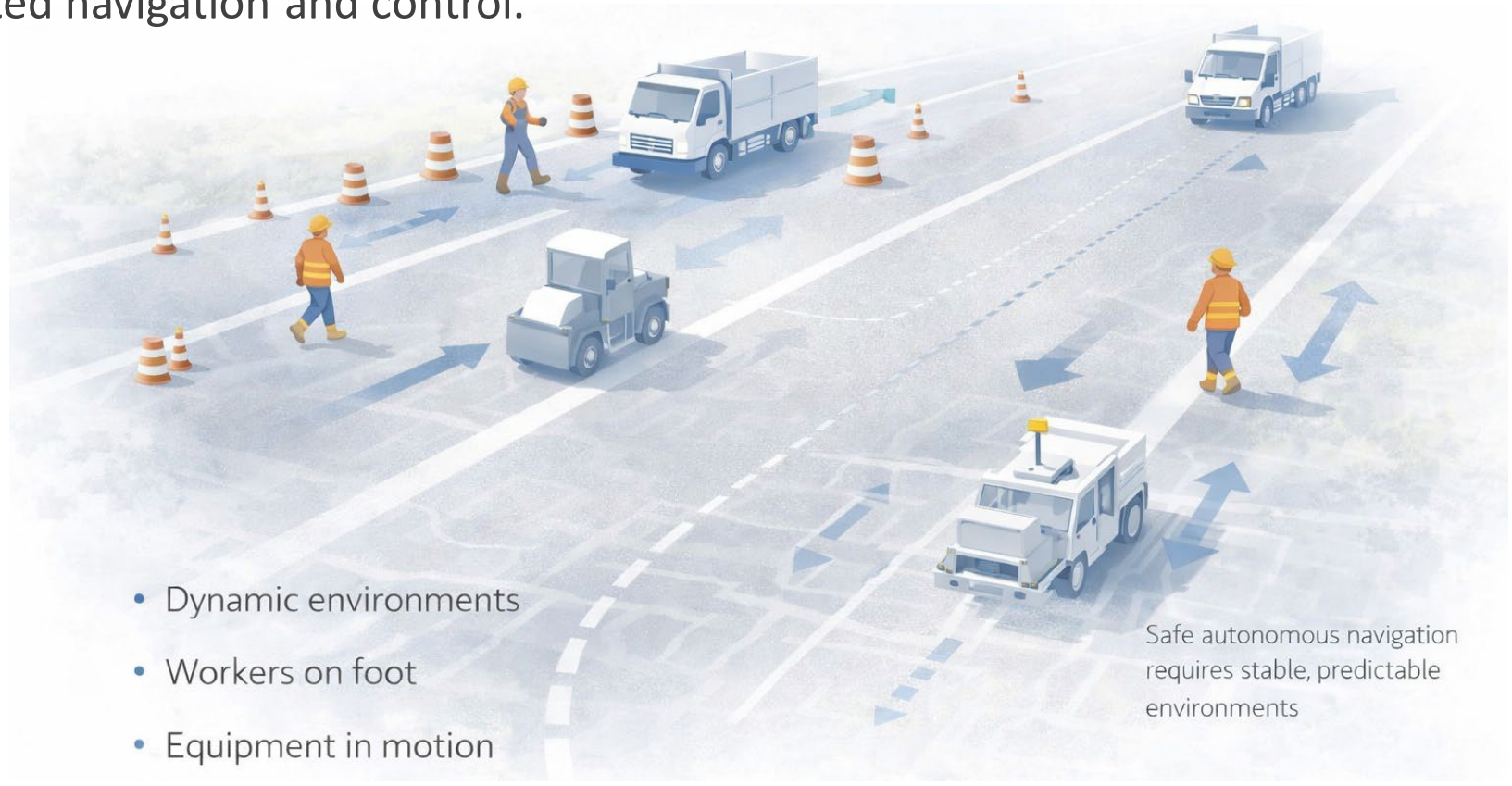
•Uploaded limited project files



•As-built data collection during operations Manually / Automatically

Barrier 2: Work Zone Complexity and Variability

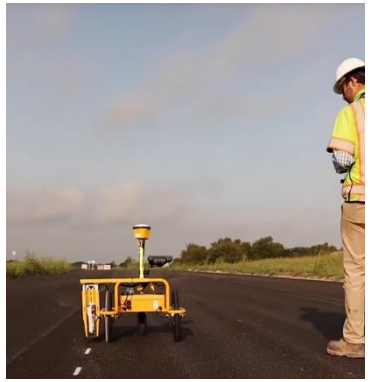
The unpredictable and dynamic nature of live work zones presents significant challenges for automated navigation and control.



Separating Application Automation from Vehicle Navigation

Automation strategies in work zones vary in scope, with many approaches prioritizing automated application while maintaining human control of vehicle navigation to manage risk.

•Walk Along



•Follow/Lead

•Auto-Steering*

•Smart Carriage

Application vs. Vehicle Automation

Barrier 3: Dependence on GNSS and Connectivity

Most automated systems depend on satellite positioning, which is vulnerable to environmental disruptions.

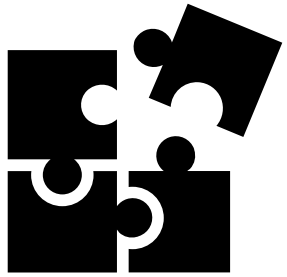
Approaches to Managing Connectivity Limitations

To manage positioning and connectivity limitations, automation systems employ a range of strategies that support reliable operation within defined automation levels.

- Inertial navigation

- Site-based GNSS reference stations

- Vision-based replication systems (Camera/LiDaR)



- New technology

Replication as an Alternative Automation Path

Replication systems enable automation by following existing markings, offering an alternative path on the automation scale.

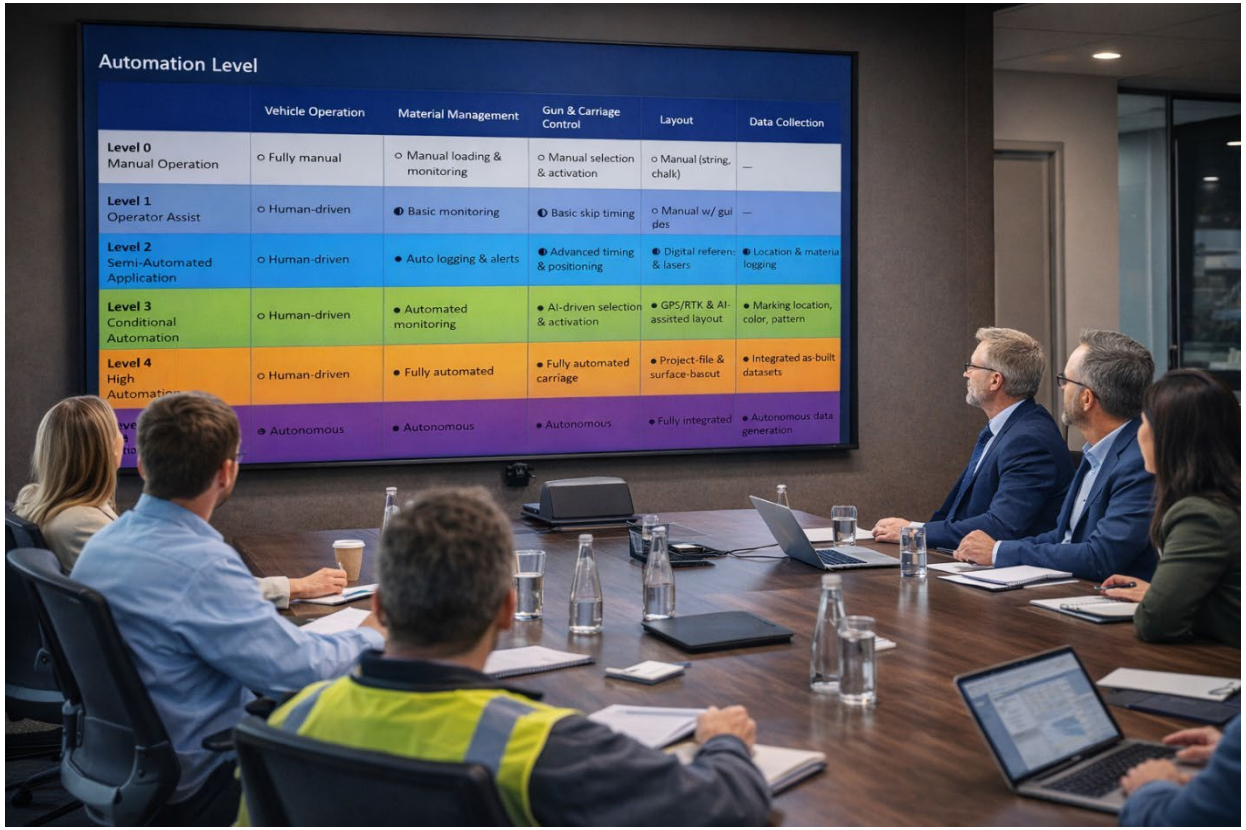
- Vision-guided following
- Maintenance applications
- Contrast dependent

Example: Replication-Based Automation

Implications for Industry, Agencies, and Research

A pavement marking automation scale helps align industry, agencies, and researchers around capability and responsibility.

- Shared terminology
- Realistic expectations
- Better collaboration



Designing Automation for Real-World Deployment

Leadership in automation means making deliberate decisions about where technology improves safety today and where human control remains essential.

- Safety-first design
- Practical deployment
- Responsible advancement

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Coming Soon…

https://LimnTech.com/pavement-marking-automation/

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Providing clarity, supports safety, and helps guide the responsible advancement of pavement marking automation.