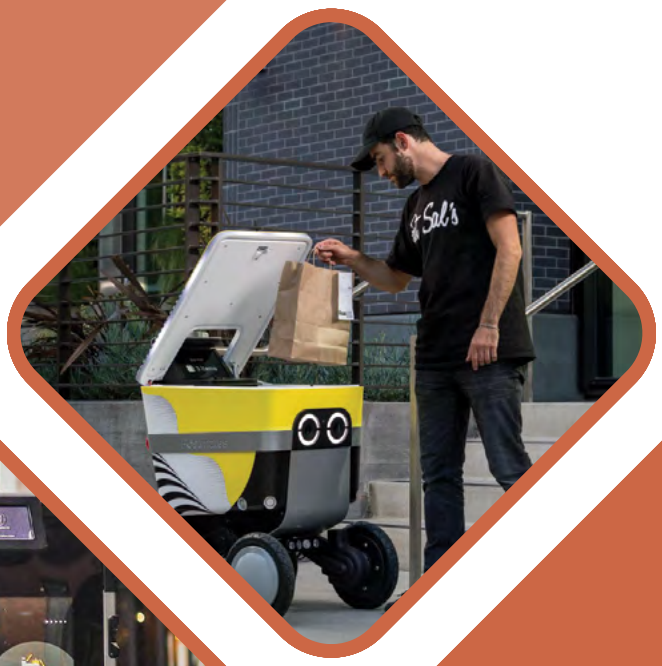
Urban Robotics Foundation



What you need to know about Public-area Mobile Robots

Executive Guide to PMRs

2025 Edition

Bern Grush
Lee St. James

urbanroboticsfoundation.org

Table of Contents

Executive Director's Message

Bern Grush - Director of the Urban Robotics Foundation

As ISO's global lead for drafting ISO DTS 4448: Intelligent Transport Systems—Public-area mobile robots, and with over 30 years of experience in transportation-related standards, I've seen how important open standards are for successful technology deployment. The key is integrating these standards into practical decision-making, particularly when designing and implementing regulations for governing, scaling, orchestrating, and managing this technology.

Welcome to the Urban Robotics Foundation's 2025 Executive Guide to Public-area mobile robots (PMRs)!

Executive Summary

City leaders and planners face mounting pressure to prepare for mobility automation technologies. While many cities have adapted to ride-hailing, many others are still struggling with bike lanes and micromobility. Very few have begun addressing robotaxis and delivery robots. We have likely covered less than 10% of the journey envisioned for new mobility.

The Urban Robotics Foundation's 2025 Executive Guide addresses the emerging field of public-area mobile robots (PMRs) — automated devices operating in public spaces among non-involved and inattentive bystanders.

PMRs represent the next evolution in mobile robotics, moving beyond controlled industrial environments into indoor and outdoor public spaces such as sidewalks, bike lanes, crosswalks, malls, airports, hospitals, and similar environments. Applications range from delivery and maintenance to security and personal mobility assistance, with adoption expected to progress from simpler environments and use cases to more complex applications over the next decade.

Key market drivers include:

- Technological advances in AI, robotics, and automation
- Demographic shifts creating labor shortages
- Growing urban service demands
- Rising operational costs
- Need for 24/7 service delivery

Our Executive Guide recommends a **"go-now-but-go-slow"** approach to PMR adoption, balancing innovation with risk management. This strategy enables organizations to:

- Learn from early deployments while minimizing investment risks
- Build public acceptance gradually
- Develop internal expertise
- Influence technology development and standards

Success in PMR deployment requires coordinated development of:

- International technical standards
- Municipal regulations and governance frameworks
- Infrastructure adaptation and investment
- Stakeholder engagement to ensure public acceptance

The URF, through its leadership in the drafting of **ISO standard 4448**, provides guidance for safe, consistent PMR deployment while addressing critical deployment concerns around safety, accessibility, and public acceptance. This guide emphasizes the interconnected nature of innovation, urban needs, standards, and governance in shaping successful PMR integration into public spaces.

If you have any questions, please reach us at:
www.urbanroboticsfoundation.org/contact

Navigating Change and Risk

We stand at a crossroads where automated systems and artificial intelligence are transforming mobility and offering increasingly sophisticated automated services. These technologies offer tremendous potential while generating legitimate concerns. A city manager seeking to address labor shortages may see PMRs as a management solution, while a person with mobility challenges might view them as either a threat or an opportunity for enhanced accessibility.

The challenge extends beyond achieving benefits like labor savings, sustainability, or cleaner and safer environments. The real test is ensuring cities and facility operators realize clear value while protecting and serving all community members. This is particularly challenging because we are introducing automated devices without visible human oversight into spaces shared with uninvolved, untrained, unprotected, and potentially inattentive bystanders.

Critical gaps must be addressed in establishing design principles, standards, and regulations for integrating PMRs into public spaces and public life. The success of PMR deployments will depend on how well we bridge these gaps while managing both the opportunities and risks of this technological transition. URF's standards work, training and advisory services help leaders navigate these challenges effectively.

“I am not calling for deregulation. I am calling for **regulation with clear rules**.”

- Ahti Heinla, co-founder of Skype, Starship Technologies

(Sillerkiil)

What are Public-area Mobile Robots?

Robots are designed in a near infinite array of sizes and purposes. Most are used in work or industrial environments. Until recently, these devices were generally affixed and often caged in a specific work location. One early exception is a small consumer robot to vacuum floors in homes.

The fast-rising mobile robot with its experimental origin in Stanford in the early 1970s, became commercially viable by 1985 as the **industrial mobile robot (IMR)** with many applications on farms and in factories. A later stage of innovation called the **autonomous mobile robot (AMR)** saw explosive growth in warehouse applications by 2000. A major difference between IMRs and AMRs is the growing reliance on sophisticated digital technologies that simplify navigation infrastructure and greatly expand their spatial flexibility.

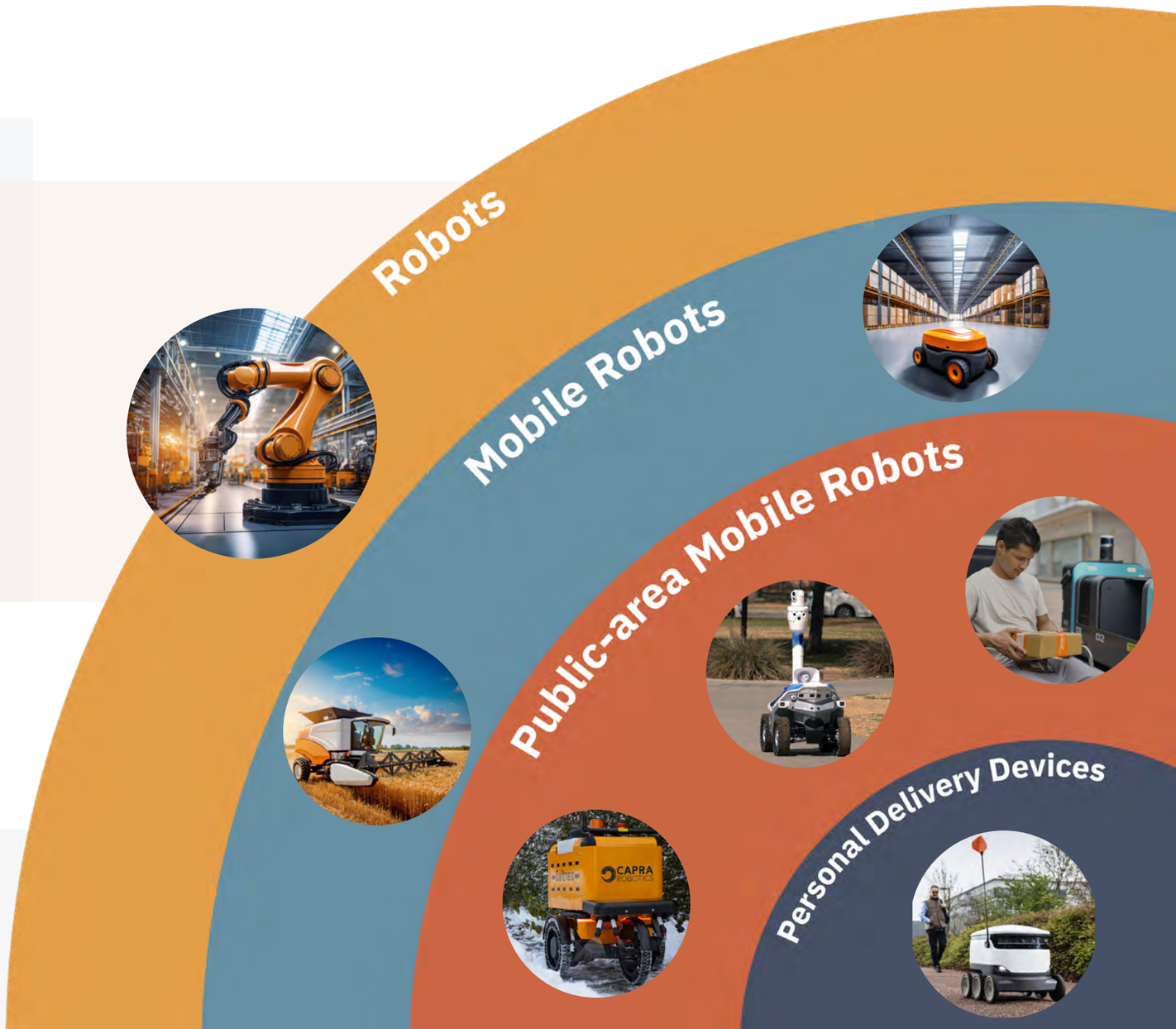
Since 2015, mobile robots have become still more capable and are progressively moving into more complex and dynamic spaces and for a variety of use-cases. The focus of the Urban Robotics Foundation is the **public-area mobile robot (PMR)** that operates in public spaces among non-involved, untrained, unprotected, and inattentive bystanders, such as pedestrians, cyclists, micromobility users and motorists. PMRs use any number of wheels, legs, or tracks.

Currently, the most popular type of PMR is the delivery robot or **'PDD' (Personal Delivery Device)**. They are most often used for "last-mile" food delivery, but new use-cases are constantly being tested and deployed in many locations.

The International Organization for Standardization (ISO) defines a public-area mobile robot (PMR) as: ***"a wheeled or legged (ambulatory) ground-based device that is designed to travel along public, shared, pedestrianized pathways without the use of visible human assistance or physical guides"***
(ISO/TR 4448-1:2024 Intelligent transport systems—Public-area mobile robots (PMR) Part 1: Overview of paradigm.

PMRs are managed with an amalgam of automation and teleoperation. Some are 100% teleoperated while others claim '99% automation.'

PMRs can also be used to carry humans as passengers (e.g., a wheelchair or assistive scooter robot) and they can be electronically tethered to follow or lead a human.



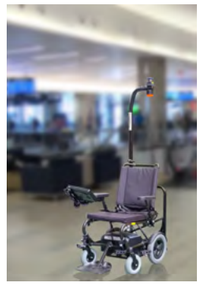
Use Cases

PMRs can be used for many applications ranging from cleaning to patrolling to moving people. Where permitted, PMRs can operate in public spaces such as airports, campuses, hospitals, malls, pathways, parks, sidewalks, and zoos. They can be used both indoors and/or outdoors.

Mobility Assistance

Demand for automation in mobility support for elderly and disabled individuals will develop as:

- Demographics shift toward aging populations
- Healthcare costs rise
- Robot-human interaction capabilities improve
- Social acceptance of robot assistance grows



Public Safety and Law Enforcement

Integration of mobile robots into law enforcement will require:

- Advanced AI decision-making capabilities
- Robust ethical frameworks
- Public acceptance and trust
- Legal and regulatory framework development

Parking Management and Enforcement

Mobile robots for parking enforcement and management will likely gain traction as:

- Cities seek to optimize parking revenue
- Labor costs for enforcement rise
- Integration with smart city infrastructure improves
- License plate recognition and payment systems mature

Emergency Response Support

These robots might carry supplies, provide preliminary assessment, or support first responders in dangerous situations. Support robots for emergency services will become more common-place as:

- AI capabilities improve
- Trust in autonomous systems grows
- Integration with emergency response protocols develops

Delivery

Last-mile delivery robots are gaining traction, particularly in urban areas with high delivery demand.

Several factors drive this trend:

- Growing e-commerce and local delivery demands
- Rising labor costs and delivery worker shortages
- Controlled user environments in university campuses and planned communities
- Integration with existing delivery operators and infrastructure

Hospitality

Robots that provide services in hotels and restaurants are becoming increasingly familiar in many cities, where they are important to address labour shortages, high turnover, late and over-night shifts, and costs (especially in developed countries). They provide:

- Host, greeting and concierge functions
- Luggage transport to/from rooms
- Room service delivery for towels, toiletries, and food
- Food and drink running to tables, dish collection back to kitchen
- Cleaning and sanitization of common areas

Cleaning and Maintenance

The pressing need to maintain public spaces efficiently is driving early adoption of mobile robots. Cities face increasing pressure to maintain cleanliness while managing costs. Autonomous floor cleaning robots, already common in controlled indoor environments like malls and airports, are expanding to outdoor spaces. These robots benefit from relatively simple, repetitive tasks and defined operational areas. The technology builds directly on existing indoor autonomous cleaning solutions, making the adaptation more straightforward than other applications.

Security Patrol and Surveillance

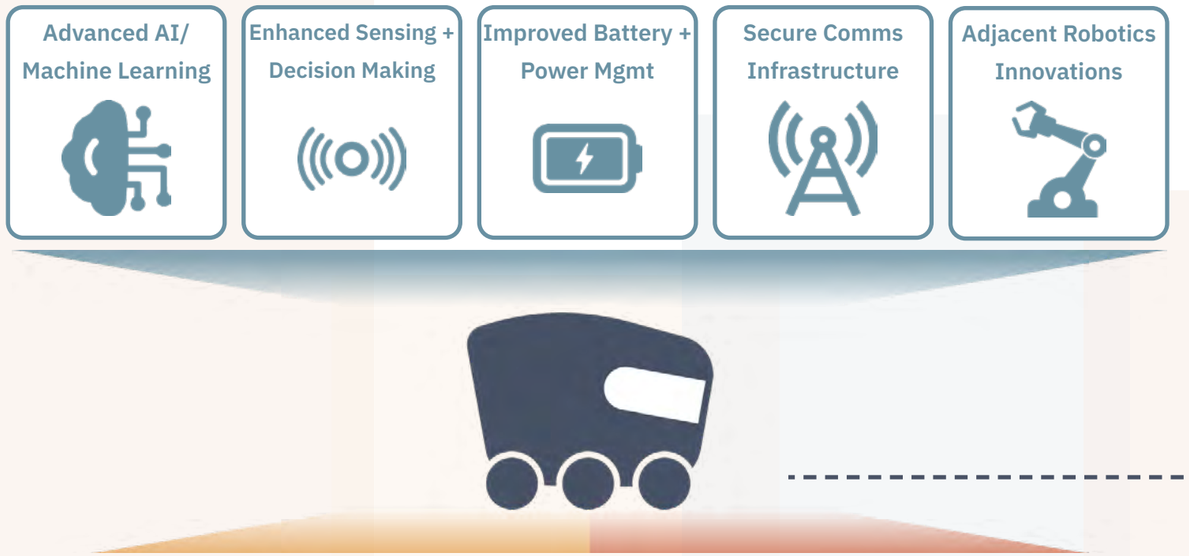
Mobile security robots are finding early adoption in semi-controlled environments like parking lots, airports, corporate campuses, and public parks. They offer:

- 24/7 operation capability
- Integration with existing security systems
- Cost-effective supplement to human security personnel
- New methods for parking management
- Consistent monitoring and reporting

The Path for PMR Adoption

The adoption of public-area mobile robots (PMRs) is becoming inevitable, driven by converging technological, demographic, and economic forces. The timing and sequence of implementations may vary, but the direction is clear. Each successful application paves the way for others, though this evolution will take time.

Technological Enablers:



Drivers of Adoption

Demographic Changes
- Aging workforces
- Labor shortages
- Rising labor cost
- Resistance to immigration

Urban Environment
- Demand for 24hr services
- Budget constraints
- Shifting mobility patterns
- Changing urban demographics

Together, these forces create both opportunity and urgency for cities to explore automated solutions. While challenges remain, the convergence of enabling technologies, demographic pressures, and urban needs makes PMR adoption a question of “how” rather than “if.”

Challenges

Technical hurdles include operating reliably in unstructured environments, managing weather impacts, and ensuring reliable operations. These challenges are compounded by the need for robust power management systems and maintenance protocols.

The regulatory landscape means cities must develop comprehensive frameworks addressing liability, insurance, safety standards, and public space usage rules. Privacy concerns and surveillance implications require careful consideration, as these systems collect data in public spaces.

Social and cultural acceptance must be earned through demonstrated reliability and transparency. Concerns about job displacement need to be addressed through clear communication about how PMRs will complement rather than replace human workers. Cities must also ensure PMRs enhance rather than hinder accessibility and equity in public spaces.

Infrastructure requirements present both challenges and opportunities. Cities need to:
- Integrate PMRs with existing smart city plans and systems
- Develop charging and maintenance networks
- Ensure secure communication infrastructure
- Create effective operating protocols

The Path Forward

Successful PMR implementation requires a **methodical approach**:
1. Begin with **clear automation strategies** aligned with specific city needs.
2. Start small with **controlled pilot projects**, then expand based on demonstrated success.
3. Invest strategically in **infrastructure** while actively **engaging the public** to build trust.
4. Develop regulatory frameworks, forge partnerships with technology providers, institutions.

Initial successes in controlled environments will build confidence for broader deployment—a compelling reason for our recommended **go-now-but-go-slow approach**. Eventually, PMRs will integrate comprehensively with other smart city systems, enabling more sophisticated and coordinated service delivery.

Success on this journey requires balancing attention to technological advancement, public acceptance, regulatory frameworks, and clear value demonstration. The opportunity is significant—PMRs can help address pressing urban challenges while improving service delivery efficiency. However, realizing these benefits requires careful planning, appropriate technology selection, and thoughtful implementation that considers both technical capabilities and social implications.

PMR Governance

The emergence of PMRs represents a complex interplay between technological innovation, urban needs, standards development, regulatory frameworks, and governance systems. These elements form a dynamic ecosystem where each component both influences and responds to the others, creating multiple feedback loops that shape the successful adoption of PMR technologies and the quality of life for the people impacted by these innovations.

Key Feedback Loops

The success of PMR deployment depends on recognizing and managing these interconnected relationships. When one element changes—whether through technological breakthrough, new standards, or regulatory update—it creates ripple effects throughout the system. For example, AI innovations in human-robot interaction might enable new applications, requiring standards updates, which then influence regulatory frameworks and governance systems.

Critical Success Factors

Adaptive Governance

- Flexible frameworks that evolve with technology
- Clear processes for updating regulations
- Balanced stakeholder involvement

Responsive Innovation

- Technology development aligned with urban needs
- Solutions that anticipate regulatory requirements
- Integration with existing urban systems

Collaborative Standards Development

- Input from multiple stakeholders
- Regular updates based on deployment experience
- Balance between innovation and safety involvement

Coordinated Regulation

- Alignment with international standards
- Consideration of local contexts
- Clear pathways for technology adoption

The maturation of PMR technology and deployment represents a complex adaptive system where success depends on the harmonious interaction of multiple elements. Innovation drives possibility, urban needs provide direction, standards ensure consistency, regulations establish boundaries, and governance systems provide oversight. Understanding and managing these relationships is crucial for successful PMR integration into urban environments.

As cities continue to evolve and face new challenges, the importance of maintaining flexible yet robust frameworks becomes increasingly apparent. The future success of PMR deployment will depend on maintaining productive feedback loops between all system elements while ensuring that technological advancement serves the public interest through appropriate standards, regulations, and governance structures.

International Deployment Standards

Until recently, international standards for mobile robots have predominantly focused on controlled working environments such as medical facilities, farms, warehouses, and factories. These standards are now expanding as PMRs introduce new complexities related to deployment in public spaces and movement among bystanders unrelated to the robot's activities.

An ISO project (**ISO 4448**) is underway to establish internationally recognized standards that enable safe, consistent, and efficient deployment of PMRs in public spaces while providing a foundation for municipal regulations, certification processes, and risk management.

This comprehensive, multi-part technical standard addresses **several key areas**:

Safety and operational standards govern speed, size, weight constraints, situational awareness, journey planning, shared-space traffic management, extreme weather limitations, multi-fleet orchestration, work-specific spatial considerations (e.g., lawnmowing, snow removal, cleaning), bystander comfort (noise, lights, passing distances), and hazardous cargo handling.

Human interaction standards specify inclusive signaling systems for all bystanders (including those with visual or hearing impairments), behavioral protocols for shared pathways, accessibility features, personal assistance capabilities, autonomous human transporters, and operational signage requirements.

Infrastructure integration standards define path sharing protocols, narrow passage navigation, pathway suitability metrics, and traffic signal system integration.

Municipal framework standards cover identification, certification, licensing, insurance, performance monitoring, remote tracking, enforcement, crash reporting, emergency coordination, and shared mapping system maintenance.

Data privacy and cybersecurity standards align with existing standards to ensure consistency with other municipal systems.

The International Organization for Standardization (ISO) is an independent, non-governmental organization with a membership of 169 national standards bodies. Through its members, the ISO brings together experts to share knowledge and develop voluntary, consensus-based, market-relevant, standards that support innovation and provide solutions to global challenges.

Our role in drafting ISO-4448

Bern Grush, URF's Executive Director, is the project lead for drafting the **ISO 4448 Intelligent Transport Systems** standard for the parameters and procedures for PMR behaviour and deployment: https://www.iso.org/standard/81068.html. This draft standard is arranged into a series of parts, addressing numerous critical deployment matters.

Members of URF participate in the development of these standards. This provides you with access to early drafts, opportunities to provide input into their content, and a head-start in preparing for their deployment.

Key elements of the multi-part ISO 4448 standard series address comprehensive **safety requirements**, focusing on concerns such as bystander protection, PMR performance across all operating conditions, navigation competence, system redundancy, and emergency response protocols. The standard extends to **infrastructure considerations,** establishing requirements for robot-infrastructure communications and evaluating the suitability of existing urban environments for automated mobility and others. Additionally, they encompass crucial **operational aspects**, including certification and liability frameworks, data privacy and security measures, density control in public spaces, robot-to-human communications, equipment specifications like speed and weight limits, and protocols for safe road crossing.

About the Urban Robotics Foundation

Urban Robotics Foundation

The Urban Robotics Foundation was established in 2021 as a non-profit, member-supported organization. URF brings together global stakeholders interested in the opportunities and challenges of public-area mobile robots (PMRs) and helps shape related international standards.

Our goal is to build a global network focused on understanding how PMRs can enhance urban livability.

The Urban Robotics Foundation creates pathways to PMR readiness with a focus on accessibility through four key initiatives:

1. Publishing a series of Guides to PMRs
2. Conducting workshops (virtual & in-person)
3. Providing vendor-independent advisory services
4. Leading the project to draft the ISO DTS 4448 deployment standard for PMRs

The early years for this technology will bring lessons; we will need to learn from those. Risks can be mitigated with careful testing through pilots and trials from which lessons can be shared.

The Urban Robotics Foundation is here to help!
Join us at urbanroboticsfoundation.org!

Acknowledgements

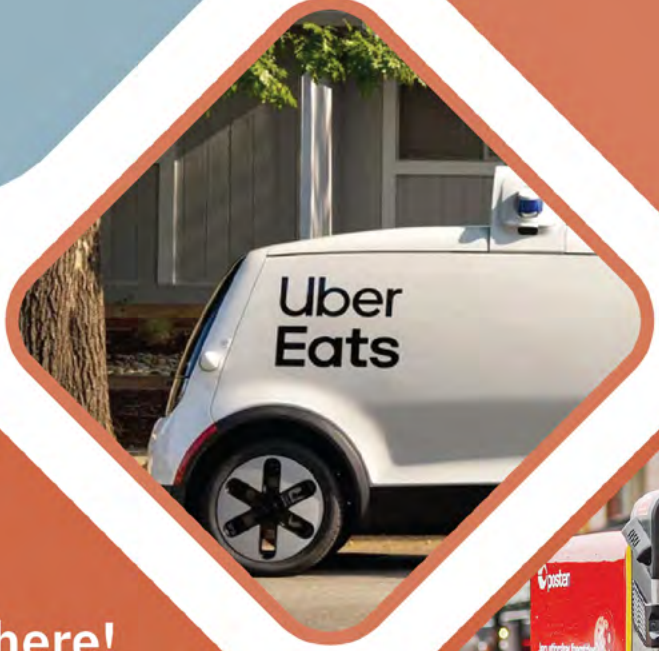
Thank you to our supporters, members and sponsors who make our work possible.

If you are not already a member, **we invite you to join the Urban Robotics Foundation** to become more engaged with our community. Member benefits include strategic networking for setting up pilot projects and sharing of key learnings/best practices, early access to review and help shape the ISO draft standard, and the opportunity for discounts on products and services provided by URF and our affiliate partners/ organizations.

Thank you for your interest in preparing for the deployment of public-area mobile robots and for reading our Executive Guide to PMRs.

Please visit **www.urbanroboticsfoundation.org** for more information on URF membership, to sign up for our free newsletter, and to inquire about our other publications, webinars, workshops, and advisory services.

Lee St. James, Managing Director URF
Bern Grush, Executive Director URF
2nd Edition - February 2025



Follow us here!