A Regulatory Roadmap for Public-area Mobile Robots

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***Abstract*—A public-area mobile robot (PMR) is an automated or teleoperated device without a proximate human operator that moves within a public space shared with pedestrians, pets, cyclists, micromobility devices and automobiles. This paper examines the current status of ISO standards and traffic regulations from several countries related to PMRs. It covers PMRs operating indoors or outdoors in public access spaces for cargo, food delivery, guidance, maintenance, and security tasks. It then outlines the regulations cities, regions, and countries need to govern PMRs, including those operating inside public-access buildings and the order in which they are needed. Finally, it recommends a roadmap for governments to prepare regulations suitable to their infrastructure, populations and polity.**

Keywords—autonomous mobile robots, facilities management, intelligent transportation systems, municipalities, pedestrian infrastructure, public-area mobile robots, public-works

I. Introduction

Mobile robots able to perform numerous tasks in public spaces began appearing in a few cities and campuses about a decade ago [1]. These devices help with delivery, maintenance, security, and innumerable other human-scaled activities while sharing the same physical spaces as pedestrians, bicyclists, automobiles, and micromobility users. The International Organization for Standards (ISO), in a draft document series, refers to these robots as public-area mobile robots, and provides the definition:

A public-area mobile robot (PMR) is a "wheeled or legged (ambulatory) ground-based robot designed to travel along public, shared, active transportation pathways without the use of visible human assistance or physical guides" (ISO DTS 4448).

By this definition, PMRs operate in public places (outdoor and indoor "active transportation pathways") where proximate human bystanders can be expected to be uninvolved, unprotected, untrained, and inattentive.

There is a growing body of viable PMR use cases, some of which may become valuable and possibly critical for some cities or populations, especially those with aging demographics. PMRs are already executing tasks such as autonomous wheelchairs in airports or hospitals, floor cleaning and security in shopping malls, hospitals and airports, food delivery via sidewalks or within campuses, lawn mowing, roadway crossing guards for students and seniors, security patrols, sidewalk de-icing, and many other uses.

For many PMR use cases, a lack of regulations is a barrier to those benefits. This, in turn, diminishes the value of investing in innovation. Instead, the ability to anticipate the nature and direction of PMR regulations would inspire innovation within given regulatory constraints. Since PMR adoption is likely to differ from one locale to another while standards are developed nationally or internationally, many jurisdictions will require regional and local regulation.

Until commercial robotaxi operation was allowed in a few cities, governments had never before permitted the operation of machines that move among unprotected and untrained humans without proximate human oversight or direct mechanical control. Such human *bystanders* are treated as obstacles by the navigation and spatial-awareness systems of these devices, including their remote oversight or teleoperation components. Permission to operate PMRs expands the operational design domain (ODD) from the roadway and crosswalk to encompass sidewalk, bike lane, and hallway. This means many cities will require regulations to govern the presence and use of PMRs in addition to the regulations required for autonomous roadway vehicles.

Such PMR regulations may initially focus on human safety, security, and privacy, but will eventually expand to encompass robot-to-human communication to ensure human understanding of the immediate next actions of a PMR. This is critical for bystander anticipation of PMR behaviour in the same way that humans now anticipate the intention of nearby pedestrians, cyclists or motorists by observing their movements, sounds, and gestures [2]. It will be necessary to regulate PMR uses and behaviours so that bystanders are safe and can readily anticipate PMR actions. Nowhere will this be more important than when a PMR is crossing a roadway.

Even if a governing jurisdiction wishes to ban PMRs for most purposes, it is likely that at least some will be required for special circumstances—perhaps for the disability community or emergency services. It may be undesirable or unachievable to fully exclude PMRs from public space.

This paper will describe a very short history of PMRs, list some of their applications, overview the state of standards and regulations related to their deployment, identify current, related legislation from a small number of countries, criticize the insufficiency of this early legislation, and outline a regulatory roadmap proposed to aid cities and their senior governments to begin the process of drafting necessary and sufficient regulations to govern deployment

II. Background

A. *From factory and warehouse to the sidewalk and street*

Mobile robot history began in the late 1960s when DARPA funded a Stanford Research Institute project for an early, mobile robot called Shakey [3]. Fast forwarding through five decades of industrial robots leaving cages to navigate via embedded wires, beacons, dead-reckoning, indoor positioning systems, maps, and visual landmarks, these mobile robots have had their most significant economic impact in factories, farms, mines, and warehouses.

For PMRs, our focus starts in 2014 when mobile robots for small personal deliveries—usually food—began operating in several places among human bystanders [4]. These have met with considerable interest and low-volume success in many cities in Estonia, the United Kingdom, the United States and several other countries [5]. In many Asian countries such as China, Japan, Singapore, and South Korea these robots have been seen as critical for serving aging populations with increasing demand for delivery services and diminishing labour to provide them [6].

Over this first decade and across many applications, PMRs have been designed to operate on roadways, bikeways, and walkways among uninvolved and unprotected humans.

B. Recent criticism of available standards

Any national or international standard that describes a technology or process to be regulated would be a valuable resource for the development of government regulations. As of 2024, there is a considerable gap between available standards for PMRs and what is needed for this task.

A 2021 paper, examining ISO 13482:2014 "Robots and robotic devices—Safety requirements for personal care robots," argued

"…the standard is not suitable for guaranteeing people's safety when these robots operate in public spaces. Specifically, the standard lacks requirements to protect pedestrians and bystanders. The guideline implicitly assumes that private spaces, such as households and offices, present the same hazards as in public spaces. We highlight the existence of at least three properties pertaining to robots' use in public spaces. These properties include (1) crowds, (2) social norms and proxemics rules, and (3) people's misbehaviours." [7]

A year later, the same authors observed

"Limiting the number of robots to prevent undue proliferation may not be an easy issue, especially in free market societies. … New policies are required to regulate mobile robot deployment in public areas, including task, speed of motion and to enforce adequate training of robot's end-users … It becomes an issue of public policy to determine the right trade-off benefits and harms brought by robots in public space. Perhaps some robots may be prioritized over others (e.g., robotic wheelchairs vs. delivery robots) because of greater human benefits (consequences), or because the 'right' for a human's autonomous locomotion in a robotic wheelchair exceeds the social value of speedy delivery of a consumer product." [8]

C. An expected surge in PMR demand and supply

Multiple drivers predict the growth in utility of PMRs in urban contexts. Demand for goods movement is driven by expanding e-commerce, while growing urbanization drives security and maintenance requirements. Growth in all three are driven by aging demographics and their implications for labour.

Supply is driven by innovation, especially in mechatronics and AI. What is available now in terms of technical capability and commercial deployment is the start of a classic S-curve for PMR diffusion. Agreeing with Salvini et al [7,8], we can expect substantial, likely exponential, growth in terms of capability, application types, and fleet sizes.

In 2021, the City Council of Hamburg, Germany published "Urban Logistics Hamburg—Strategy for the last mile," which targeted a maximum of 45 percent of last-mile shipments by light commercial vehicles, and 95 percent of deliveries with emission-free vehicles, by 2030 [9].

Such targets, commonly set by many cities, require more than environmentally cleaner vehicles. In order to address sustained expectations for same-day and same-hour delivery, steady increases in per capita delivery demand, and continuing labour shortages, a considerable technology mix is needed. Logistics automation will mature and micro-fulfilment will grow in significance. This means labour intensity will be increasingly focussed at the last mile and/or the last 50 meters. These scenarios are the most difficult part of the supply chain to staff or automate—hence, the most rewarding to solve.

Seemingly unavoidable, labour shortages alone will pull innovation and investment toward last mile solutions. Delivery PMRs—both wheeled and ambulatory—will play a critical role within a mix of small electric delivery vans, cargo-bikes, e-bikes, and secure locker systems. Such PMRs will collaborate rather than compete with other delivery modes since delivery PMRs are likely to operate as another mode in each carriers' fleet. Indicative of this is the manner in which the company, Uber Eats, trialed at least three different PMR companies by making robot delivery an option for the receiver within their crowd-sourced delivery app [10,11].

Concurrently, cities are seeking ways to encourage active transportation, reduce automotive traffic and street parking, create complete streets, shrink traffic lanes and dedicate more of the urban right of way for pedestrians, cycling, micromobility and microtransit. Moving e-commerce deliveries out of cars and vans and onto cargo bikes is an important contributor to this effort. Delivery PMRs are poised to contribute as well.

D. New draft standards for PMRs

In 2020, the ISO commenced a standard for mobile ground robots operating in public spaces and intended to be useful for writing regulations potentially to be harmonized within regional and national jurisdictions.

The draft standard series, *ISO 4448 Intelligent transport systems—Public-area Mobile Robots (PMR)* is expected to be published in 2025-2026 and addresses PMR deployment, behavioural, and governance matters while they move among bystanders without a proximate human operator [12].

The ISO 4448 series is focussed on open, unstructured operating domains shared with human bystanders. It encompasses navigating, distancing from others (proxemics), waiting, communicating next intentions, loading, unloading, crossing roadways, spatial awareness, journey data recording, suitability of pathway infrastructure, weather-related operation, crash-reporting, map maintenance, personal assistant robots operating in public space, multi-fleet orchestration, multiple safety issues for bystanders, enforcement, and vandalism mitigation.

Key for the 4448 series is safety and comfort of human bystanders and users of common public space. The series provides terminologies, definitions, metrics, operating ranges, and procedures that can be used to define deployments and the regulatory systems to manage, orchestrate, and enforce behaviours within those deployments as well as potentially monetizing their usage.

Some PMRs are arguably a type of social robot due to their operation in proximity to, and sometimes directly interfacing with, humans. This implies a social aspect. However, many PMRs perform maintenance or surveillance with no direct interface other than spatial cooperation, hence the social dimension of PMRs ranges broadly. For this reason, ISO 4448 focuses on spatial collaboration more so than the higher order social aspects critical to personal care robotics, providing continuity between what Salvini et al [7] saw as missing in ISO 13482 and what ISO 4448 is intended to provide.

III. What regulations are needed?

In spite of this, the ISO 4448 draft is insufficient to guide PMR deployment within given urban locales due to variations in each. Operational deployment requires regulations specific to a city or region. The ISO standard provides global guidance that may be adapted for local application. Regional and local regulations will be required to match local infrastructures, densities, traffic systems, and population preferences.

There are early examples of regulations specifically developed for a type of PMR known as a personal delivery device (PDD) or a sidewalk automated delivery robot (SADR). PDDs generally use walkways or bikeways to deliver parcels between a unique shipper-receiver pair equivalent to a bicycle courier delivering a package—although some larger PDDs may carry multiple deliveries in secure compartments while navigating bikeways or roadways.

In all cases, these regulations have been developed as amendments to existing motor-traffic rules. Estonia, Finland, Japan, South Korea, and 22 U.S. states [13] have passed legislation to increment existing traffic rules so that PDDs can operate on one or more of walkway, bikeway or roadway. Each of these amendments describe a minimum subset of safety dimensions related to size, weight, speed, place of operation, brakes, lights, insurance, etc., in addition to general pedestrian-like behaviour when using sidewalks and crosswalks. Unfortunately, several of these dimensions vary considerably in the current U.S. State House and Senate bills [13]. If left unharmonized, this presents an unnecessarily complex body of rules for national PMR operators to follow in that country.

Worse than disharmony, this early legislation addresses only PDDs with the notable exception of recent updates to Estonia's Traffic Act [14]. That is reasonable if one considers urban traffic systems to only move passengers and goods, so that security or maintenance PMRs transporting neither passengers nor goods can be excluded. But PMRs deicing sidewalks, sweeping streets, or on security patrol may use the same shared walkways or bikeways in addition to crossing roadways. Hence, while not a transportation device per se, non-PDD PMRs share the same mobility space, and must follow regulations—almost certainly similar to those that a PDD would follow—with respect to the use of shared mobility infrastructure.

In addition to this sole focus on PDDs in amendments to existing traffic rules, some PMRs will be physically able to use multiple infrastructures. There's no engineering reason that a robot cannot be designed to navigate bikeways, corridors, crosswalks, parking lots, pedestrian plazas, shopping malls, sidewalks, stairs, or trails—all shared public spaces. How should governments regulate mobile devices that operate across multiple infrastructures, both indoors and out?

It is not germane whether a single device will do all of these, but it matters that many devices will be competent to do most of them. Not only will regulations be required for each of these operating domains, but regulations will be required for most transition circumstances for any PMR that can move from one to another.

An example of this is in draft ISO 4448 clauses describing *PMR behaviour on human pathways.* These provide behavioural procedures designed for a PMR to approach, wait, enter, and cross multiple types of roadway intersections. In this case, the walkway–crosswalk interface often bridges two (or more) levels of government, such as city and state or city and country. Any jurisdiction that governs behaviour at traffic intersections must consider how to adopt and enforce those behaviours it may see as critical for a PMR to cross a roadway.

Another instance arises for a PMR that is able to navigate on any of walkway, bikeway and roadway. Local regulations may be needed to determine if, where, and when a PMR may transition from one to the other. The guidance offered by 4448 may be sufficient for a PMR manufacturer or operator designing to execute this behaviour, but it is insufficient to inform operator permission within a particular shared space.

IV. PMR regulatory roadmap: Problem statement

The objective function of a regulatory roadmap is to minimize the total cost of regulatory development and compliance for PMRs. It will be necessary to develop regulation in stages due to its complexity and because the systems to be regulated are not yet fully disclosed. While PMRs may continually innovate for many decades, they require regulation throughout all stages of their deployment.

A. Current Context

There is considerable interest in innovating and trialing PMRs for many applications from both private and government investors. Hence, it is essential to continually reconsider how viable this technology will be for operation within current urban infrastructure and social environments.

There is a potent contradiction in investing in PMR innovation without close consideration of how its deployment will be regulated. It is certainly important to consider matters such as size, speed, object avoidance, and multiple safety aspects. But, without a view toward PMR traffic, infrastructural, and social facets, it is easy to imagine that many, if not most, cities will severely constrain—and possibly ban—the use of these devices in public spaces among untrained bystanders. In fact, extensive constraints and occasional bans are the current norm [15]. A lack of regulations has contributed to this.

Banning PMRs is currently, and will likely remain, appropriate in some temporary circumstances, and certain use-constraints will almost always be appropriate. A proposal for a regulatory roadmap is to make it possible for cities wishing to leverage this technology to do so with greater public acceptance and confidence. A proposal for regulation is not an indication that PMRs should be admitted any more than the existence of traffic regulations is an indication one should purchase a motorcar.

B. Current status

Early PMR innovators make and operate small fleets, often providing services on behalf of another entity (robots-as-a-service). As technology matures, intermediary operators lease

or purchase fleets of these devices (robot-services-as-a-service), becoming responsible for regulatory compliance.

Until now, most deployments support small fleet sizes and a single fleet operator deploying a homogenous type of PMR. This is changing. Already some facilities are standing up multiple robots from multiple manufacturers and performing various robotic tasks within a common location. At the same time, there are instances of PMRs from independent operators moving in both indoor and outdoor public-access spaces. In one case, a U.S. city that permitted PMRs from two independent companies has already experienced traffic conflicts at road crossings. Such conflicts could be mitigated via regulations that are currently lacking.

It is impossible to anticipate the details of all coming PMR innovations or the likelihood they will be broadly accepted. Nonetheless, developing a roadmap to detail aspects that need to be addressed, and in which order, should begin.

C. *What is required*

A roadmap for PMR regulation should address the following purposes or circumstances:

1. To provide a foundational basis at the appropriate national, state, provincial, or regional level of governance especially regarding traffic safety and public security governance as well as road use including road crossings.
2. To inform municipal needs for setting times and places of operation, behaviour when using/sharing public spaces, and enumerating numerous local permissions and constraints. Such regulations would likely rely on and conform to regional safety and governance regulations. Many PMR rules must be adjusted for variability in local infrastructure and circumstances, including social and political preferences. Many municipalities will need opportunity, means, and guidance to develop local bylaws.
3. Guidance for regulating PMR use in commercial, public or government buildings and outdoor spaces. This includes the use of maintenance or other service robots within hospitals, retail buildings, or other places where members of the public may visit or congregate without requiring knowledge or awareness of these devices.
4. Autonomous wheelchair PMRs that transport passengers in airports, hospitals, or other public facilities and places because of the incremental safety concerns when transporting humans.
5. Privately owned/rented PMRs that accompany, follow, or lead a pedestrian companion while navigating a public pathway or within a public building.
6. Matters such as traffic orchestration, licensing, monetization, and enforcement as PMR technology expands in fleet counts, size and variety of applications.
7. Address hazardous goods and weaponization. This should be addressed nationally or internationally given that developing technology is likely to find ways to move between countries autonomously.
8. Address harmonization as effectively as possible to maximize human comfort, familiarity, and safety around PMRs while maximizing their utility, including social utility, wherever they are encountered.

V. PMR REGULATORY ROADMAP: PROPOSED APPROACH

A. *Operating domains to address*

PMRs comprise a broad scope of possible use cases, public operating environments, traffic circumstances, and social concerns; no single legislative process or document will be sufficient to address all. Of the 25-plus jurisdictions that have modified their roadway regulations to accommodate personal delivery PMRs for using sidewalks, crosswalks, and roadways, only one admits non-PDD use cases [14]. This a critical gap in that many other types of PMRs are designed to concurrently navigate the same public travel spaces, including crossing roadways.

Maintenance PMRs executing public works in the proximity of uninvolved bystanders will require municipal bylaws. They will also require definition within traffic regulations if they are operating on road shoulders or are able to navigate crosswalks. This implies that a PMR operating in a city's public space might be governed by national, state or provincial regulations as well as municipal legislation. Such regulations should be harmonized to minimize the total cost of regulatory development and compliance.

For example, PMRs that will clean floors, move cargo, act as autonomous wheelchairs, etc., within airports may require national regulation in some countries to address definitions, weights, speeds, signals, brakes, and numerous safety matters, while also needing regulations or guidelines from the local airport authority concerning local operations and traffic within concourse and terminal areas shared by human bystanders. Similarly, PMRs that operate on city streets and crosswalks may be regulated by at least two levels of government such as municipal and state or provincial.

Final legislative approaches will differ among countries according to which level of government is accountable for regulating corresponding operating domains and how each country chooses to integrate new regulations. As mentioned, international harmonization will likely be needed for hazardous goods, weaponization, and possibly other topics.

B. *Issues to address*

The first detailed step is a roadmap to identify the required regulation purposes and the interconnections among its elements, including:

- Safety
- Accessibility
- PMR behaviours, both social and navigational
- Governance including operation, certification, licensing, monetization.

C. *Critical guidance necessary*

The regulations required to guide urban PMR deployments span more far more than the traffic laws which have been the focus of PMR regulations to date. Regulators now need distinctions for:

- Levels of regulatory depth to be executed sequentially and with future steps in mind at each level of:
  - Trials and pilots—study purposes, small numbers, limited areas, temporary duration;
  - Early deployment (100s of PMRs)—one or a few small fleets; low variability in place, task, & purpose;

- Middle deployment (1000s)—large, multiple fleets; modest variability in place, task, & purpose; requires ground traffic control & monetization;
- Mature deployment (10,000s)—increasing size, sophistication and diffusion of fleets; regional orchestration.

- Enumeration of, and requirements for, each level of operational demand, including infrastructure, traffic management, licensing, and enforcement.

Regulators will require roadmaps for regulating traffic in outdoor spaces shared with pedestrians and vehicles including wheelchairs, bicycles, micromobility devices and road vehicles vs. indoor spaces shared almost entirely with pedestrians and fewer, slower micromobility devices. Such roadmaps may be independent of each other or be constructed with shared concerns and mutual vocabularies. The latter approach is best.

Defining degrees of interconnection, independence, and common terminology early in the regulatory process is crucial. For instance, there would likely be a high correlation between the traffic regulations for delivery PMRs and security PMRs for navigating within a crosswalk but a lower regulatory correlation between floor scrubbing PMRs and autonomous wheelchair PMRs even though both may be operating in an airport concourse.

The balance of common definitions and terminologies with independent deployment purpose is critical. The current manner in which technologies operating on roadways and technologies operating within buildings are regulated may be largely independent; however, engineering—including mechatronics and intelligent software—is not constrained by these same boundaries. Hence, it is not practical to consider a single volume of common regulations or a single uniform roadmap for all PMR applications or deployments. At the same time, having completely independent roadmaps with distinct vocabularies and without harmonization would create an undue drag on the related industries and on the value PMRs can bring to public mobility, public safety, and public facilities.

Hence, the initial roadmap stage should enumerate and seek concurrence on as many components and interrelationships as feasible before commencing with development of specific model regulations.

D. When to start

The development of a regulatory roadmap should start immediately with the understanding that any regulations described will be developed in multiple stages and require time to stabilize. The immediate undertaking should describe necessary elements, identify the regulatory aspects needed, and recommend an order of development.

E. Recommended approach

The full body of regulations needed at a regional or municipal level cannot be developed in a single step:

- There are a large number of independent aspects, especially among sectors such as security, maintenance, and logistics.
- Within a single sector, such as maintenance, there will be regulatory variances among devices according to the designed task (e.g., a de-icing PMR operating on sidewalks will be different than a sweeping PMR that operates on the roadway, although it is very likely that regulations with respect to crossing a roadway would be common).

Hence, the structure of municipal regulations will be multi-faceted. While they will not be developed in a single step, they will also not be developed as entirely independent elements. There will be some regulations that apply to all PMRs, a few that apply to many subsets, and others that apply to only a specific type of PMR.

For these reasons, the first step is a roadmap that identifies each of the required elements, their common clusters of concern, the specific elements to be regulated, and finally the order in which they should be drafted.

F. Major steps

1. Draft a high-level roadmap—identify each level and enumerate and define the elements at each level. This is the overview of the expected remaining steps and may require adjustments as the process proceeds.
2. Develop a model regulation for walkway, bikeway, roadway and crosswalk navigation using the combined learnings extracted from extant (25+) legislation that address PDDs. Present this model so that a region or municipality can select and adjust the elements it chooses for incorporation into its appropriate legislative format and then-current requirement.

   While this is an appropriate starting point, it may be insufficient for a municipality wishing to deploy beyond a pilot or trial since the early PDD regulations were silent about numerous space-sharing and traffic management aspects needed beyond classic traffic regulations.
3. Expand the scope of the first model to incorporate any PMRs that can operate in the same spaces. Specifically, address non-transport PMRs (e.g., security, maintenance, guidance) that can move autonomously within any active transportation space.
4. Identify and define detailed regulations for safe roadway crossing, including the use of walk signals at signalized intersections and operational rules for PMRs using crosswalks. (Existing regulations that rely on an assumption of pedestrian-equivalent behaviour are both insufficient and ambiguous for teleoperators and automated driving system (ADS) software. Pedestrian behaviour is highly variable and complex; teleoperation and ADS require codifiable rules and measurable behaviours that will eventually be recordable for purposes of enforcement and insurance subrogation, according to draft ISO 4448.
5. Develop an equivalent level of public safety model regulations for PMRs operating within facilities that serve or accommodate proximate human bystanders within their operating domain.
6. Extend the regulatory models created to this point to encompass ambulatory PMRs for the environments and tasks contemplated. Note that adding or switching to legs will extend or change the nature of operating domains. A simple example is the use of stairs or the ability to climb such as a maintenance robot that can climb utility poles.
7. Extend regulatory models to include numerous PMR safety and social behaviours described in draft ISO 4448.

VI. Stakeholder Values

The work to advance a PMR regulatory model proposed in this paper would impact multiple stakeholder interests, each of which weighs value differently. For example:

Governments value PMR regulations for:

- Enhancing equity and accessibility
- Ensuring efficient delivery of public services
- A deployment and enforcement framework
- Addressing labor shortages and climate goals

The public and especially accessibility communities value PMR regulations for:

- Ensuring safety and safeguarding rights
- Seeking improved infrastructure
- Ensuring consistent and expected behaviour
- Traffic management

Investors value PMR regulations for:

- Increased foresight and opportunity
- Ensuring investment value
- Targeting resources

Universities value PMR regulations for:

- Increasing mobile robotics research realism
- Enhancing certification value
- Inspiring traffic studies and social studies

Manufacturers value PMR regulations for

- Guiding innovation
- Streamlining (focusing) R&D efforts
- Securing commercialization
- Directing deployment

VII. Summary

The common flow of innovation-to-regulation typically starts with (1) an assumption of societal and business value which draws on (2) a business model(s) to (3) drive trials and to (4) encourage diffusion. Typically, (5) unintended consequences appear, such as system or usage errors causing loss or damage. Finally, (6) losses, especially those involving human injury or death, (7) motivate regulatory activity. This is evident in the urgency for regulations related to the development of vehicle automation including systems supporting robotaxi and automated trucking business models.

PMRs, generally far smaller and slower than automated passenger and goods road vehicles are far less likely to cause severe injury or death, but cannot be guaranteed to have no harmful consequences. It is imperative that we begin to understand the regulations we will need to manage what is certain to become an extensive catalogue of devices and systems designed to operate in proximity to uninvolved, unprotected, untrained, and inattentive human bystanders.

A full regulatory process will span several decades, but its initial requirements are already anticipated given the existence of some legislation in at least five countries. This initial anticipation can be readily extended by leveraging the draft ISO 4448 standard series currently in progress.

Now is the time for governments to start framing PMR regulations.

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References

[1] https://www.starship.xyz/company/ (accessed 2024.07.02)

[2] Weinberg, D., Dwyer, H., Fox S., Martelaro, N. (2023) “Sharing the Sidewalk: Observing Delivery Robot Interactions with Pedestrians during a Pilot in Pittsburgh, PA”

[3] Perry, T. “SRI's Pioneering Mobile Robot Shakey Honored as IEEE Milestone,” IEEE Spectrum. February 2017. https://spectrum.ieee.org/sri-shakey-robot-honored-as-ieee-milestone

[4] Jennings, D., & Figliozzi, M. A. (2019). “Study of sidewalk autonomous delivery robots and their potential impacts on freight efficiency and travel.” Transportation Research Record, 2673(6), 317-326.

[5] Tänavsuu, T. (2017) “Estonian delivery robots are transforming the world.” https://estonia.ee/delivery-robots-created-by-estonian-engineers-are-transforming-the-world/

[6] Min, R., (2023) “Japan will allow self-driving delivery robots to roam its streets to combat labour shortages.” https://www.euronews.com/next/2023/02/12/japan-will-allow-self-driving-delivery-robots-to-roam-its-streets-to-combat-labour-shortag

[7] Salvini, P., Paez-Granados, D., Billard, A., “On the Safety of Mobile Robots Serving in Public Spaces: Identifying gaps in EN ISO 13482:2014 and calling for a new standard,” ACM Transactions on Human-Robot Interaction, Vol. 10, No. 3, Article 19. July 2021

[8] Salvini, P., Paez-Granados, D., Billard, A., “Safety concerns emerging from robots navigating in crowded pedestrian areas,” International Journal of Social Robotics (2022) 14:441–462

[9] Stolt, R., Jambor, M., Hoffman, J., Weber, T., Abberger, M., Heutger, M. "Last Mile Delivery 2030: How carriers, shippers, cities, and consumers need to adapt," Porsche Consulting, 2024

[10] Navlakha, M. (2023) “Thousands of delivery robots are being deployed for Uber Eats.” https://mashable.com/article/uber-eats-delivery-robotsn (accessed 2024 07 07)

[11] Yukana, I., (2024) “Uber Eats Japan begins deliveries with self-driving robots.”https://www.japantimes.co.jp/business/2024/03/06/tech/inoue-uber-eats-robot/ (accessed 2024 07 07)

[12] ISO TR 4448-1 Intelligent transport systems — Public-area Mobile Robots (PMR) — Part 1: Overview of paradigm, DRAFT, in press.

[13] Clamann, M., Podsiad, K., & Cover, A. “Personal Delivery Devices (PDDs) Legislative Tracker.” May 2023. http://pedbikeinfo.org/resources/resources_details.cfm?id=5314.

[14] Estonia (2010, updated 2024) Traffic Act. https://www.riigiteataja.ee/akt/122122023004?leiaKehtiv

[15] Grush, B. (2022) “Sidewalk robots: What happened in Toronto? (2021-Dec)” https://www.urbanroboticsfoundation.org/post/sidewalk-robots-in-toronto