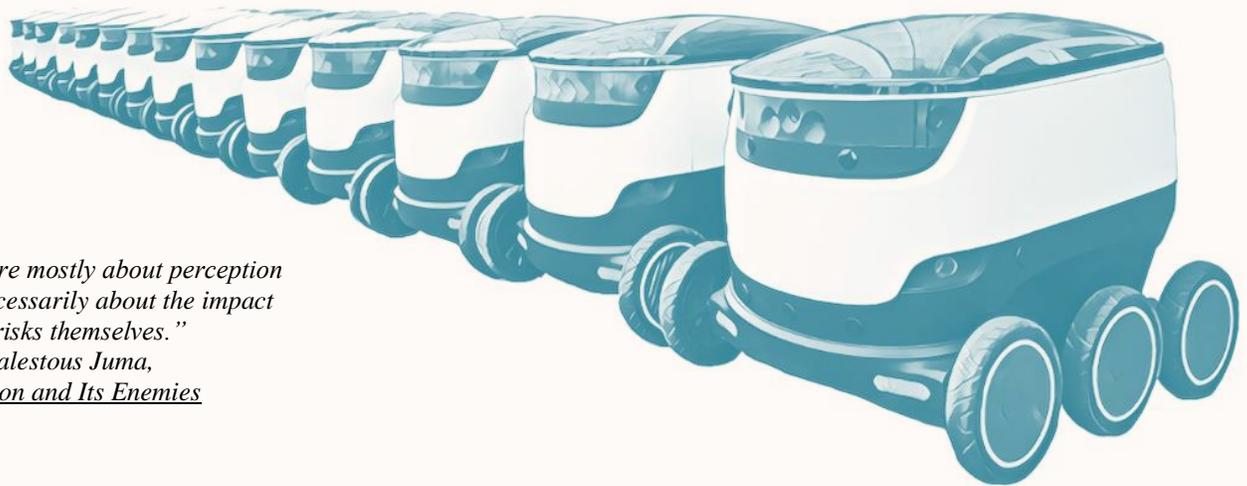


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URBAN TECHNOLOGY STUDIES: DELIVERY ROBOTS

(An Independent Policy Series Presented by the Chaddick Institute)



“The debates are mostly about perception of risks, not necessarily about the impact of the risks themselves.”

*~Calestous Juma,
Innovation and Its Enemies*

INTRODUCTION

In the past few years, our city streets have been overrun by an army of micro-mobility devices like dockless bikes and electric scooters. Furthermore, the takeover of our public sidewalks by private entities appears far from over. In fact, many cities are currently making room for another device looking to hurdle us into the future: these new wheeled robots go by many names,

including Autonomous Delivery Devices, Personal Delivery Devices, Electric Personal Delivery Devices, or simply Delivery Robots.

Using technology similar to what is found in autonomous cars, Delivery Robots (aka Personal Delivery Devices or PDDs) are sent onto our streets and sidewalks to deliver orders made through various apps and websites such as Amazon or Postmates. As

the market for home delivery continues to grow rapidly (Cheng, 2018), companies are scrambling to get PDD's approved by regulators and onto the road. Constituents and elected officials have concerns about such technology due to cases of fires ("Kiwibot delivery robot," 2018), crashes (Harding, 2019), and even awkward sidewalk interactions between humans and PDDs (Simon, 2018). To assist cities in making educated regulatory decisions, this report will address the following: 1) why PDDs are needed; 2) the technology behind PDDs, 3) the many PDD manufacturers; 4) the positive & negative externalities surrounding PDDs; 5) the current regulations; and 5) ideas on how municipal officials can simultaneously embrace this new technology while at the same time embracing them.

APPROACHING PEAK DELIVERY

Historically, perishable items and groceries such as produce, milk, eggs and ice were delivered directly to people's homes. During the late 1800's and early 1900's appliances and even homes were ordered by mail and delivered to the customer (Abid, 2018). Home deliveries of perishable items eventually declined due to the advent of refrigeration, the adoption of automobiles and the birth of supermarkets (Muller, 2015). Today, we are at a new crossroads as we quickly approach *peak delivery* with more and more online shoppers demanding their orders delivered within hours after the orders are placed (Premack, 2019). In fact, a 2016 report by McKinsey & Company estimates that autonomous vehicles will make up 85% of last-mile deliveries by 2025 (O'Brien, 2018). Food delivery services such as Uber Eats and Deliveroo also add to the growing on-demand movement. As we re-enter an age where direct delivery is considered a requirement to many consumers, companies able to crack the last mile delivery equation stand to reap huge rewards.

AUTONOMOUS TECHNOLOGY

Due to this emerging trend, PDD's are being paid increasingly more attention from legislators and investors. As a result, they join an already crowded field of autonomous innovators; autonomous cars and drones have both made headlines in recent years and have received widespread attention from city and state governments ("Autonomous Vehicles," 2018). Although they differ in many ways, PDD's share a great deal in common with other autonomous vehicles. For further insight on the varying (and overlapping) technologies found in autonomous vehicles, see the infographic published in *MIT Technology Review* (2018) which readers can [link-to here](#).

Like their self-driving cousins speeding down highways, PDDs use a number of tools to maneuver through crowded sidewalks. There are *sensors and cameras* that collect data and process it in real-time to insure the vehicle travels safely in the correct lane; *artificial intelligence* that continually enhances vehicle performance and is aided by new algorithms through the cloud; *data processors* that transmit real-time calculations to allow high-speed decision-making; and *GPS* to track the location of the vehicle. There are also *artificial intelligence systems* and algorithms that allow the vehicle to adjust to varying circumstances, as well as *RADAR* that uses radio waves to determine the where surrounding objects are. *Cloud-based data processing* aggregates and evaluates real-time telemetric data (I.e. vehicle speed, surrounding car proximity) to inform braking or turning, while *LIDAR* technology senses break lights and changing road conditions. Meanwhile, *Smart Technologies* can converse with road signs, traffic lights, and lane markers, the *Internet of Things* supports machine-to-machine communications, and *active sonar* uses sound waves to detect objects in the environment.

The technology listed above has been integral in the rapid advancement of driverless cars,

and they are now crucial to the engineers developing DDPs. While makers of self-driving cars have been intent on using as many tools as possible to prevent accidents and mistakes, when it comes to PDDs, robots developers are able avoid some of the greatest concerns regarding autonomous car safety. For example, several delivery robot developers have opted to have robots stop in their tracks when faced with a human in their path on a busy sidewalk.

While the idea of a two-ton robot hurtling down a highway at 60 mph is likely to keep legislators up at night, developers of PDD's are hoping that their relatively slow and cautious 40 lb. robots will slip by without too

much fuss. After all, because they move slowly, the likelihood that delivery robots will see numerous fatalities akin to driverless cars (Wakabayashi, 2018) or even shared mobility devices is unlikely (Schmitt, 2018). PDDs use much of the same caution as driverless cars but without the high stakes.

Autonomous vehicles are understandably a point of great trepidation for everyone who walks or drives on our public roads and walkways. However, when mistakes are inevitably made in the autonomous race, it is likely that we would rather have them occur on our sidewalks at 2 mph rather than our highways at 60 mph.

Personal Delivery Device Technology vs. Autonomous Vehicle Technology

	Personal Delivery Devices	Autonomous Vehicle
Sensors & Cameras	X	X
Machine Learning	X	X
Artificial Intelligence	X	X
Local Data Processors	X	X
High Performance GPS	X	X
RADAR	X	X
LIDAR	X	X
Cloud Data Processing/Management	X	X
Connectivity to the Internet of Things	X	X
Smart Technologies	X	X
Inertial Measurement Unit	X	X
Active Sonar	X	X
X = Yes		

VENDORS & MANUFACTURERS

Several companies have already entered the race to put PDD's on the road. Perhaps unsurprisingly, Amazon has been investing heavily in this technology; the Seattle-based behemoth has already deployed a test program in Snohomish, Washington and hopes to expand the program in 2019. As for its competitors, companies like Starship Technologies are making waves by launching in Redwood City, California, London, and Washington, DC.

It appears that Starship Technologies was the initial leader in the field but Nuro now surpasses it in funding. Although these two companies will likely continue to be innovators in the field, Piaggio and of course Amazon are companies that are well established and have resources to invest.

As the race heats up and technology continues to advance, we may see a flurry of buyouts as Amazon seeks to secure its control of the home delivery market and companies like Uber and Lyft seek to increase their market share.

Company Name	Funding (Millions)	Cities of Operation	Founded In	Founded Date	Partnered With
Starship Technologies	\$42.2	Redwood City, London, DC	San Francisco, CA	July 1, 2014	Postmates, DoorDash, Sodexo, Mercedes Benz, Dominos Pizza
Marble	\$10	San Francisco	San Francisco, CA	Feb, 2015	DoorDash, Yelp Eat24
Amazon, Scout	Public	Snohomish, WA	Seattle, WA	Jul 5, 1994	
Kiwi Campus	\$2	Berkeley, CA	Berkeley, CA	2016	Udacity
BoxBot	\$9	NA	Oakland, CA	2016	
Nuro	\$1,032	Scottsdale, AZ	Mountain View, CA	2016	Kroger
Piaggio Fast Forward	NA	NA	Boston, MA	Jun, 2015	
Robby Technologies	\$5.5	Bay Area, CA	Palo Alto, CA	Mar, 2016	PepsiCo, Postmates
Aitonomi TeleRetail	\$1.1	NA	Sierre, Valais, Switzerland	2014	

POSITIVE EXTERNALITIES

What are the benefits and drawbacks of having PPDs on our streets? Yes, these robots take up limited sidewalk space – space which is also being chipped away at by other emerging technologies including dockless bikes and e-scooters. However, if managed well, these Personal Delivery Devices have the potential to solve many of our urban issues.

Elderly Assistance:

For aging populations, shopping and cooking can be challenging tasks, particularly for those living alone. These communities could therefore stand to benefit significantly from the advent of PPDs. These devices are a cost-effective and fast means of receiving medication, groceries or other items, and they stand to completely change the lives of individuals with mobility challenges (Hicks, 2017).

Environmentally Friendly & Efficient:

The sheer efficiency of these products may also prove to far offset their downsides. In 2013, UPS and FedEx began using electric bikes where streets are narrow and parking is limited (Roberts, 2014). However, using PPDs for last mile delivery would be even more efficient and could benefit the environment. PPDs could help reduce the number of large delivery vehicles forced to double park, cause congestion, add to vehicle miles traveled, and ultimately add to greenhouse gas emissions (Wood, 2018).

Affordable Delivery:

Currently same-day, free delivery by Amazon is a massive expense, requiring carriers and Amazon to spend tens of billions of dollars a year. The of bulk delivery costs are due to last mile delivery (Lufkin, 2015). Consequently, same-day deliveries, which are inherently small distance deliveries, are immensely expensive. As shipping costs continue to rise, companies like Amazon need to maintain convenience and cut delivery costs (Semuels, 2018). PPDs provide a convenient alternative

to human-centered deliveries at a fraction of the cost.

Increased Safety:

Despite some early setbacks, PPDs may prove to be safer than the alternatives. Delivery drivers deal with rampant danger (“Pizza Delivery Driver,” 2013), and rank fifth on the list of most deadly jobs in America. Replacing a person with a robot means putting fewer people in a precarious position, often late at night, dealing with cash. In addition to the safety of drivers, delivery robots may help to keep pedestrians safe. Companies like Amazon are already cutting corners to save on delivery costs. In some cases, drivers are pushed by to take chances to meet expectations; when this happens, accidents can occur, and pedestrians pay the price – as was the case in one Chicago neighborhood sharing its streets with Amazon drivers (Savini, 2018). If there is one thing we know about PDD’s and their designers, it is that they want to avoid accidents and negative publicity at all costs (Diaz, 2019).

Also, seeing that flying drones are potentially more dangerous (Bown, 2018) and legislation for them could prove to be far more complex (Marcontell & Douglas, 2018), PPDs might prove to be the better option.

Education & Community Development:

One PDD company, Kiwi Campus, partnered with Udacity, an online education program, to train 200 new engineers in Colombia with Udacity’s Self-Driving Car Nanodegree (“Kiwi Campus Announces,” 2018). The company also looking to build the first Kiwi Factory in Medellin, Colombia, with a state-of-the-art assembly and research and development center. Piaggio Fast Forward, another PDD company, partnered with state and local economic development agencies and has plans for a hands-on apprenticeship program that uses the state-of-the-art robotics and engineering as the centerpiece of their training (“Piaggio Fast Forward Announces,” 2018). This technology possesses many potential benefits for communities, especially

in the area of training and education. Cities would be smart to harness this potential and create partnerships with public schools and colleges to encourage Science, Technology, Engineering and Mathematics (STEM) education.

NEGATIVE EXTERNALITIES

Potentially, using robots for deliveries will bring value to our cities; however, technology developers are still working out the kinks. Although PDDs are almost completely self-sufficient, they still require monitoring by human “*Minders*,” the employees tasked with monitoring these devices. Recently one PDD ran into a parked car (Harding, 2019), and the incident was blamed on the minder. Similarly, a robot in Berkeley, CA recently caught fire and was destroyed in the middle of the street (“Kiwibot delivery robot,” 2018), again with the minder taking the blame. As of yet, the technology for these devices is not perfect.

Furthermore, cities still need to catch up before PDDs can really take off. Much like the onslaught of e-scooters and dockless bikes prompted city governments to pass legislation curtailing their use and restricting their permitted locations, we may see sidewalk gridlock before we achieve widespread localized policies for PDDs.

Relatedly, there is the problem of congestion. Ideally, scooters and bikes can be tucked into easy-to-avoid areas, but PDDs will be amongst human traffic, adding to the congestion of our walkways. Individuals who are particularly young or old may interact poorly with these machines or be unable to get out of their way easily.

Liability is another issue that needs to be addressed. Imagine a jogger hurtling down a steep incline in San Francisco’s North Beach district, turning a corner, only to find a PDD underfoot. Imagine a patch of ice in a Chicago neighborhood causing a PDD to slide into oncoming traffic. City attorneys and

lawmakers will need to address these and many other such scenarios.

In addition to these challenges, the arrival of delivery devices in our economy heralds yet another step toward the automation of jobs. Autonomous trucks, taxis, and delivery devices will be pouring onto an economy already shaken by many manufacturing, crop cultivation, fast food and shipping jobs lost to robots in recent years. In many cases, food delivery is the largest and fastest-growing source of revenue for small food-based businesses. In a thriving economy, we seem to be narrowing the field of unskilled labor and, sooner or later, our elected leaders may need to take action to calm the tempestuous job market. Automation will have a disproportionate effect on minorities and lower income individuals who disproportionately occupy trucking, delivery and manufacturing jobs.

REGULATIONS

PDDs may be the most viable autonomous vehicle to gain speedy legislative approval. The prospect of a two-ton car without a driver will give regulators more pause than 35 lb. pizza delivery robots that remind us of R2D2. In fact, the average person might be surprised to find there have been several municipalities and states that have already passed legislation allowing Personal Delivery Devices. These forward-thinking cities include D.C., Austin, TX, and San Francisco, CA. The states include California, Virginia, Florida, Idaho, Ohio, Wisconsin, and Arizona (Schwartz & Zaidi, 2018). The main themes of current legislation fall into four categories: 1) Operations & Maintenance; 2) Service Area; 3) Fleet size; and 4) Safety Requirements.

1. Operations & Maintenance

It is hard to imagine how these devices will be greeted by community members. Many shared mobility device providers are already struggling to discourage vandalism. It seems likely that as the public is developing familiarity with PDDs, many of these devices

will meet an unfortunate end (Lazo, 2018). Companies operating these devices will need to find ways to discourage vandalism and ensure that maintenance is provided for an entire fleet numbering in the hundreds and, someday, thousands. Idaho's PDD [House Bill 204](#) includes a "compliance review" which is an on-site examination of motor carrier operations, including vehicle maintenance and inspection, financial responsibility, accidents, hazardous materials, and such other related safety and transportation records to determine safety fitness.

2. Service Area

City space is finite and local elected officials will need to decide where these devices will be allowed to operate. Government officials are presented with three primary choices: permit PDDs to operate 1) in the streets; 2) in bike lanes; and/or 3) on sidewalks. There are pros and cons for allowing operation of PDDs in each of these areas. In Austin, PDD fleets are limited to city-owned "pedestrian-ways" to avoid issues with state-owned "pedestrian-ways." Washington D.C. prohibits PDDs in the Central Business District and requires device removal within 24 hours of breakdown.

Sidewalks: According to the Federal Highway Administration, sidewalks require a minimum width of 5.0 feet if set back from the curb or 6.0 feet if at the curb face in order to meet the requirements for people with disabilities. In areas near schools, arenas, parks, and shopping districts, the minimum sidewalk width is 8.0 feet. 4.0-foot-wide sidewalks (permitted as an American Association of State Highway and Transportation Officials minimum) leave little room for large groups of people and can force pedestrians to walk in the street. Now, add a robot 48 inches tall and 24 inches wide to such a sidewalk and space becomes extremely limited ("Walkways, Sidewalks, and Public Spaces," 2013). San Francisco allows PDDs to operate in permissible testing areas such as: zoning districts designated for production; non-high injury areas; and

sidewalks that can accommodate wheelchairs and devices and are at least 6 feet wide.

Bike Lanes: Cyclists already have enough obstacles to worry about without adding PDDs to their list of things to dodge during a commute. PDDs might exacerbate the daily issues faced by cyclists and might end up being another obstacle that puts them at risk for injury. On the other hand, PDDs might make city streets safer for cyclists, as they could result in fewer delivery vehicles double parking in the bike lane. Washington D.C.'s pilot legislation states that PDDs cannot interfere with bicycle traffic (no operation of PDDs in bike lanes).

Streets: Visibility is the biggest issue if PDDs are required to operate in the street. PDDs are equipped with lights, noisemakers, and a flag, but when these device stand at a mere 18 to 36 inches tall, it will definitely be hard for drivers to spot them, which could lead to accidents or worse, drivers swerving and hitting a pedestrian.

3. Fleet Size

Fleet sizes vary by city. For example, Washington D.C. currently allows 5 devices while San Francisco allows up to 9 devices at any time. These allotted fleet sizes are on the conservative side during the pilot programs, but if the pilot is successful, it is inevitable that PDD vendors will be allowed to increase the number of devices in operation.

4. Safety Requirements

Policy makers are already struggling to address concerns about the safety of shared bikes and e-scooters which have caused dozens of injuries and even deaths in recent months and show no sign of slowing down (Lekach, 2019). Safety is obviously the most important part of any proposed legislation from the perspective of both elected officials and constituents. Some of the main considerations include PDD speed, noise, flags, lights, brakes, and, perhaps most importantly, the Human Operator

Breakdown of Existing Regulation Regarding Delivery Roots

	Washington D.C	San Francisco, CA	Virginia	Florida	Idaho	Ohio	Wisconsin
Operations & Maintenance							
Maintenance Required		X			X		
Vendor to Incur All Liability & Fees					X		
Vendor Has 24 Hours to Remove Broken Bot	X						
Accessible Contact Info on Bot		X	X	X	X	X	
Must Dock/Park on Private Property		X					
City Allowed to Observe Maintenance/Testing		X					
Fees & Fines							
Permit Fee	X	X					
Fines		X					X
Fleet Size & Service Area							
Total Fleet Size Allowed	5	9					
Side Walk Width Requirements				X			
Pilot Area (Entire City or State)			X		X		
Operations Human Interaction							
Yields to All Other Vehicles	X	X		X	X		X
Human Operator Requirement (Human Chaperone or On Standby Electronically if Problem Occurs)	X	X	X	X	X	X	X
Safety							
Visibility Requirement (e.g. lights & flag)		X	X			X	X
Noise Requirement (e.g. warning noise)		X					
Restrictions on Delivery Substances		X	X	X	X	X	
Bot Braking Requirements			X	X	X	X	X
Bot Weight Limit (50lbs maximum)	X		X				
Bot Speed Limit (mph)	10	2	10	10/15	10	10	10
Insurance		X		X		X	

Requirement which mandates a human to be on standby electronically. Starship's U.S. Head of Public Affairs, David Catania, said his company's devices have logged more than 150,000 miles without a traffic incident and have encountered more than 15 million people (Harding, 2019). Although one insurance claim was filed when a device hit a parked car, Catania attributed the incident to a "robot ambassador" not paying attention. That's a pretty good track record!

Potential for Additional Legislation: Equity Requirements

Dockless bike and e-scooter companies have made extensive efforts to provide services to lower-socioeconomic communities. PDD companies can also promote the social good in communities if they are required to provide job training programs in lower-socioeconomic communities. Legislation could require collaboration with public school S.T.E.M. classes, so communities can benefit from the technology while it's being tested in their neighborhoods. Kiwi Campus' partnership with Udacity to train 200 new PDD engineers in Colombia is something other companies could easily replicate on the south side of Chicago ("Kiwi Campus Announces," 2018). If these companies want access to our public ways, Chicagoans should receive some benefits from the arrangement beyond convenience.

ROAD MAP TO SUCCESSFUL LEGISLATION

Yes, our city streets and sidewalks have been taken over by what seems to be an army of micro-mobility devices, from dockless bikes to e-scooters to delivery robots. Nevertheless, elected officials would be wise to remember that PPDs stand to bring tremendous social good to our cities by serving the elderly and disabled, reducing greenhouse gas emissions, and increasing the safety of city dwellers. Main points for legislators to consider when allowing PDDs in their neighborhoods are:

- Human Chaperone Requirements
- Yields to Humans
- Safety Requirements (lights, flags, noisemakers, etc.)
- Speed Maximums
- Fleet Size
- Where to Operate & Sidewalk Width Requirements
- Equity Requirements (training/education in lower-socioeconomic communities)

When dealing with new technology, specifically technology we don't yet fully understand, it's important to stay grounded in science, to study the data, and only then to make calculated, informed decisions. The following quote from Calestous Juma's book, *Innovation and Its Enemies*, is a good frame of reference as we evaluate new technologies:

"The debates are mostly about perception of risks, not necessarily about the impact of the risks themselves."

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