WORLD ECONOMIC FORUM

Taxonomy for Segmentation of Autonomous Delivery Vehicles and Personal Delivery Devices

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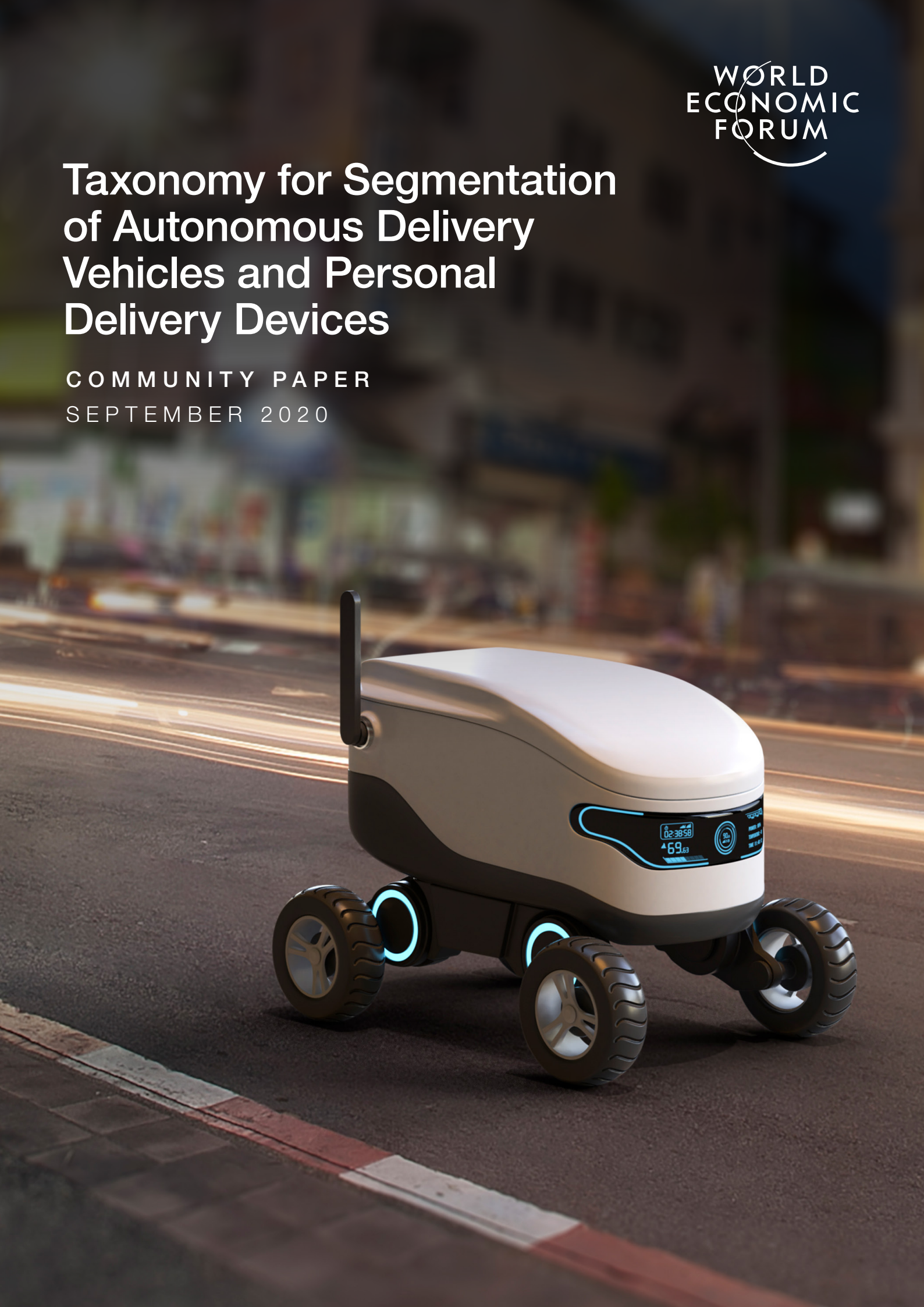

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Preface

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Delivery has become a highly attractive application of automated driving systems, spurred by a surge in online shopping and grocery delivery that is increasing the load on middle and last-mile logistics. This is compounded by a shortage of qualified drivers, which makes a compelling business case for applying autonomous technologies to the movement of goods. The COVID-19 pandemic has further catalysed the growth of this sector, as the prospect of contactless deliveries, and reducing exposure to drivers and consumers, becomes a critical objective for middle and last-mile deliveries.

To assist policy-makers in understanding these vehicles, the World Economic Forum has prepared this document to provide clear terms and the policy context for various types of automated delivery vehicles. This simple terminology is intended to be a starting point for those considering future policy solutions.

In this document, two distinct categories are defined:

– Personal Delivery Devices (PDDs)

– Automated Delivery Vehicles (ADVs)

Within each category, there are likely to be many variations in size, operational design domain (ODD)[1], sensors and other configurations. The intent of this definition is to provide broad terms for discussion and categorization of these solutions, not to provide an exhaustive list. As the technology evolves, new designs and solutions are likely to emerge, which may not exactly fit this categorization.

1 Application of this Taxonomy

In addition to creating broad governance categories, this taxonomy is intended to describe the risk factors through the use of sub-categories in order to allow stakeholders to differentiate between various designs and sizes of bot, vehicle or drone. Examples of how to apply this taxonomy are given in each category.

1.1 Personal Delivery Devices

Definition

A Personal Delivery Device (PDD) is defined as a ground-based robot which has been designed specifically for the purposes of delivering goods, and does not make full use of the public road.

The PDD may drive autonomously or be operated remotely. At this stage of development, PDDs are monitored continuously while in use. A PDD cannot carry passengers.

Where can it operate?

A PDD may operate in public spaces, such as sidewalks, parks, campuses and pedestrianized urban areas; it may also need to operate in private spaces like warehouses, shops and distribution hubs. It is not allowed full use of the road in the same fashion as a car or other vehicle, although it may periodically enter the road space as required, such as when crossing the road using pedestrian crossings. Additionally, PDDs may make partial use of the road by driving in cycle lanes or other "third spaces", according to the local infrastructure where they are deployed. While it may use some of the road, some of the time, it is not considered to behave as a full road user.

How is it built?

A PDD is typically a small vehicle with capacity for a single customer's worth of goods. A typical PDD may be designed to do single delivery trips over a short distance. The hallmark of their design is a small footprint, with an enclosed cargo box. Due to the purpose-built nature of these devices, there are likely to be many variations in design, including number of wheels, sensor configuration, size, weight and more. If a "PDD" is required to use the road in the same way as other traffic, then it becomes a "vehicle" and subsequently its design requirements will change, as described in the following section.

What is the business model or use case?

PDDs are likely to be deployed in dense urban areas, due to their limited range and operational design domain. They are suited to last-mile, business-to-consumer deliveries, as they are able to drive on the sidewalk right up to the customer's location. Although they may not be the fastest way of moving goods within a city, PDDs could be used to deliver many different types of goods, including takeaway food, groceries, packages and dry goods; PDDs may feature insulated liners and cargo boxes to improve their ability to carry fresh goods or hot food.

Who is responsible for regulating them?

PDDs currently represent a governance gap. Any restrictions on their operation are minimal, and are typically enacted on a local or municipal level. This could change in future as autonomous vehicle policy frameworks continue to develop.

Sub-categories of PDDs

It may be necessary for the purposes of governance to establish sub-categories of PDDs to differentiate between deployments. There are a number of ways of doing this; for each approach some indicative values are proposed. These categories are representative of various factors which impact the operational risk of the PDD.

By weight
As with vehicles, weight-based classification can be used as a net indicator of risk for PDDs. Proposed weight sub-categories are shown in Figure 1.

FIGURE 1: **PDD sub-categories by weight**

Class	PDD gross unladen weight
Small	≤100kg
Middleweight	101-250kg
Large	≥251kg

By speed
Maximum speed is also a strong risk indicator. Proposed sub-categories based upon maximum speed are shown in Figure 2.

FIGURE 2: **PDD sub-categories by maximum speed**

Class	PDD maximum speed
Ultra-low speed	≤5 km/h
Low speed	6– 15km/h
High speed	≥15km/h

Taxonomy application

Combining these terms would enable a regulator to specify categories of PDDs, as follows:

FIGURE 3: **Application of PDD taxonomy**

A delivery robot which does not classify as a full road-user, with an unladen weight not exceeding 100kg, and a maximum speed between 6-15 km/h

Whereby (1) indicates the risk factors and sub-category, and (2) specifies that this is not a fully road-going vehicle.

1.2 Automated Delivery Vehicles

Definition

An Automated Delivery Vehicle (ADV) is defined as an automated or autonomous car, van or truck which operates on the public roads, and carries goods, but not passengers.

Where can it operate?

An ADV will operate on public roads in a pre-determined operational design domain (ODD). The ODD places limitations not only on where the ADV can go, but may also constrain it to certain weather conditions, times of day and even traffic densities. Because they are able to operate on the roads and highways, ADVs could operate in urban, residential or extra-urban environments, depending on their application.

How is it built?

An ADV may be based upon a conventional car, van or truck, which is already type-approved to operate on the road. Alternatively, it may be a purpose-built vehicle which has been approved to the relevant market standards for road vehicles, or granted exemption from elements of these standards. Whether purpose-built or an upfitted vehicle, an ADV will feature a suite of sensors to localize the vehicle and monitor its environment and other road users. The type and configuration of sensor will vary depending on the vehicle's ODD, size and between operators. The ADV developer will develop a control system, comprising hardware and software, to drive the vehicle. For the purposes of this document, an ADV can be considered as an SAE Level 4 autonomous vehicle. More information about the SAE Levels of Autonomy can be found in their technical reference standard, SAE J3016.[2]

What is the business model or use case?

ADVs span a range of applications, and different vehicle classes may be suited to different business models. For example:

- A truck-based (i.e. class 7 - 8) ADV is most suited to long-haul, hub-to-hub logistics.
- A van-based or box truck-based (i.e. class 1 - 6) ADV is most suited to middle-mile, business-to-business distribution.
- A car-based ADV may be suited to middle-mile or last-mile, business-to-consumer distribution.

Who is responsible for regulating them?

ADVs are subject to regulation on multiple levels. The vehicle platform must meet – or be granted an exemption from – market-level safety standards, such as type approval, where they exist. These may be set by the United Nations Economic Commission for Europe (UNECE) or the US Department of Transportation, for example. Additionally, the vehicle will have to be licensed to operate, or granted a permit for development purposes. This may be administered by a national regulator, state-level department of transportation, or local licensing agency, depending on the market. The vehicle may also be subject to further restrictions at a local level, such as designating approved areas for goods drop-off. Moreover, heavy goods vehicles may be subject to additional regulations in certification and operation when compared to passenger vehicles.

Sub-categories

Retrofitted vehicles
Retrofitted autonomous vehicles are based upon existing production vehicles, which are type-approved or homologated to existing market standards (such as UNECE regulations, Federal Motor Vehicle Safety Standards). This means the base vehicle platform already meets a range of existing safety standards, covering aspects such as crash safety and occupant protection.

These vehicles are adapted to drive autonomously by installing sensors, compute hardware and drive-by-wire controls, but may also retain their conventional controls for development operators to drive them while under development. Current safety standards may require these controls to retained, regardless if the vehicle is able to operate without a driver. While the base vehicle is subject to regulation at the market level, the operation and licensing of autonomous vehicles may be subject to further national, state and local policy measures.

The majority of road-going autonomous vehicles being tested and developed today are retrofitted vehicles.

Purpose-built vehicles
Unlike a retrofitted vehicle, a purpose-built vehicle is one that is designed or extensively re-engineered to be autonomous, and is not based upon a platform that conforms to existing market standards. This means it may not feature human controls, or mirrors, for example. Hence, in order to operate on public roads, the vehicle needs to be granted exemption from the relevant market safety standards for type approval or vehicle homologation. This exemption is usually sought from the national level regulator and may require the AV operator to. In addition to being regulated at the market level, the operation and licensing of autonomous vehicles may be subject to further national, state and local policy measures.

Existing vehicle classes
For UNECE signatory markets, the 1968 Vienna Convention on Road Traffic[3] provides a harmonized starting point for vehicle classes. This segmentation provides an implicit hierarchy of risk linked to kinetic energy (through weight and speed), complexity in control (power and articulation) and human occupancy.

The United States Federal Highway Administration also sets out gross vehicle weight rating based classes (1-8)[4] which could be used alongside the initial sub-categories for ADVs. The Other nations or states may have existing classifications of vehicles (such as low speed Neighborhood Electric Vehicles), which could also provide analogous frameworks for establishing further sub-categories if appropriate. In the interests of alignment and harmonization of requirements, this taxonomy recommends applying existing vehicle classifications where possible.

Taxonomy application

Combining these terms would enable a regulator to specify categories of ADVs, as follows:

In UNECE signatory markets:

A passenger car-based automated vehicle with an unladen weight not exceeding 3,500kg.

In the United States:

A purpose-built light-duty automated vehicle which does not use an existing vehicle platform, with a gross weight rating not exceeding 6,000lbs.

A heavy-duty truck based automated vehicle with a gross vechicle weight rating in excess of 33,000lbs

Whereby (1) indicates the vehicle's class, (2) specifies that these are road-going vehicles, subject to a range of national requirements.

2 Conclusion

This taxonomy is not intended to be an exhaustive categorization of all foreseeable applications of automated driving systems to delivery use cases, but provides concrete reference terms for policy-makers to apply in setting out governance frameworks for managing these vehicles as they are developed and deployed.

The principal categories of PDDs and ADVs are established by differentiating on whether the vehicle is intended to be a functional road user, or operation in a predominantly off-the-road environment. This in turn implies whether the vehicle is subject to existing regulations for vehicles, or whether it may be subject to more localized restrictions in certain markets.

As PDDs currently represent a governance gap, the World Economic Forum recommends policy-makers consider the benefits of applying an agile, multistakeholder approach to mapping their future policy needs.

For more information on the Forum's work in Automotive and Autonomous Mobility policy, please contact us.

3 Contributors

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4 Endnotes

1. SAE Mobilus Taxonomy– Operational Design Domain, https://saemobilus.sae.org/wiki/automatedconnected/view/Taxonomy/ODD.
2. SAE J3016 – Levels of Driving Automation, https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic.
3. UNECE – 1968 Vienna Convention on Road Traffic, http://www.unece.org/fileadmin/DAM/trans/conventn/Conv_road_traffic_EN.pdf.
4. US Federal Highway Administration vehicle classes and GVWR categories , https://afdc.energy.gov/data/10380.

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