AV Use-Cases & Regulation

Egil Juliussen, Ph.D.
Consultant & Columnist EE Times
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- What are leading Autonomous Vehicle use cases?
- How do AV regulation impact AV use-cases?
- How could deployment of AV use cases evolve?

Contact info: LinkedIn: Egil Juliussen | LinkedIn

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Autonomous Trucks & Goods AVs

AV Use-Cases	Key Players
Autonomous trucks: L4 Getting increasing attention and investments due to simplicity of hub-to-hub trucking & pandemic. Mostly in U.S. and China	▸TuSimple: US & China ▸Waymo Via ▸Aurora Innovation ▸Plus: US & China ▸Embark & Kodiak ▸Einride: EU
Goods delivery AVs: L4 Desirable due to pandemic, growth of e-commerce, meal & grocery delivery	▸Delivery companies ▸Logistics companies ▸Retailers ▸Restaurants
Sidewalk goods AVs: L4 Small, walking speed	▸Starship Technologies ▸Amazon
Road goods-only AVs: L4 Purpose built for goods	▸Nuro ▸Neolix: China
Road goods AVs: L4 Vans, small trucks	▸Argo, Aurora, Waymo ▸Udelv

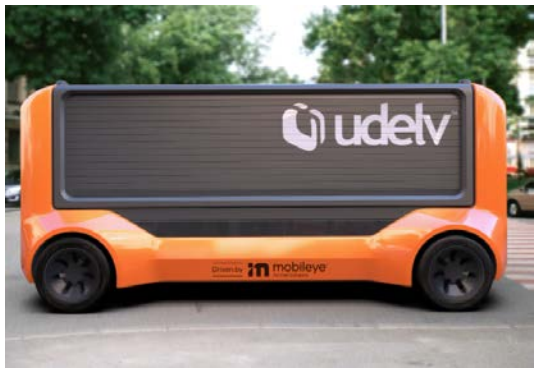
Source: TuSimple

Source: Waymo

Source: Starship

Source: Amazon

Source: Nuro



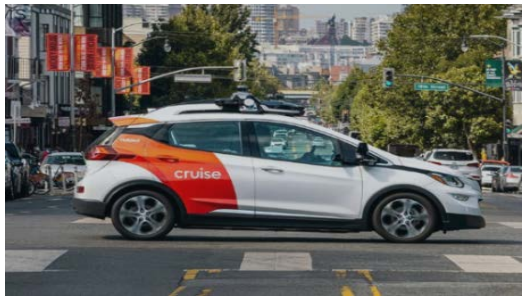
Source: Udelv

Source: Egil Juliussen; April 2021

Robotaxis & Fixed Route AVs

AV Use-Cases	Key Players
Robotaxis: L4 AVs for ride-hailing. Get most attention due to the vast market potential. Some pandemic delays. Mostly in U.S. and China	▸Waymo One: Phoenix ▸Motional: Las Vegas ▸Cruise, Mobileye, Zoox ▸Lyft, Uber & Didi ▸AutoX, Baidu & Pony.ai ▸Momenta & WeRide
Fixed route AVs: L4 Shared rides for people transport as part of smart cities & closed venues. Negative pandemic impact	▸EasyMile: France ▸Local Motors ▸May Mobility ▸Navya: France
Personal AVs: L4 Not likely until 2025+ Robotaxi-like deployment	▸Mobileye-Intel ▸Robotaxi AV software platform players

Source: Waymo; Driverless operation



Source: Cruise; BEV

Source: Zoox; No driver controls

Source: Cruise; No driver controls

Source: Local Motors; Ollie 3D printed

Source: EasyMile

Source: Egil Juliussen; April 2021

Safety: Human Driver vs. AV Software Driver 1 of 2

Issues	Human Driver	AV Software Driver
Driver's license	▶Test to prove traffic rules proficiency ▶Driving test to prove driving skills ▶Difficulty varies by state & country	▶Traffic rules built into software ▶AV software driver's license? When? How? ▶AV software testing permit variations
Driving skills & experience	▶Months-years-decades of experience ▶Few hundred miles to 1M+ miles ▶Driving skill has bell shaped curve	▶Road driving: Waymo; 25M+ miles ▶Virtual driving: Waymo; 25B+ miles ▶Driving skill has penetration growth shape
Distraction: Visual, manual & cognitive	▶Variety: kids, eating, daydreaming etc. ▶Growing smartphone distraction ▶Cause about 18% of all U.S. crashes	▶No software distraction ▶Sensors are possible visual issues ▶Very small factor in AV crashes
Speeding	▶Common problem for many drivers ▶Cause about 20% of all U.S. crashes	▶Never; not allowed in software ▶Should not be a factor in AV crashes
DUI: Driving Under Influence	▶Alcohol impaired driving is common ▶Drug impaired driving is growing ▶A factor in about 20% of all U.S. crashes	▶Not applicable ▶Could cybersecurity attacks be an issue? ▶Should not be a factor in AV crashes
Reaction Time	▶Experience & individual factors ▶Drivers' distraction level	▶Faster reaction than human drivers ▶More sensors and 360-degree view
Drowsy or tired	▶Common problem	▶Never

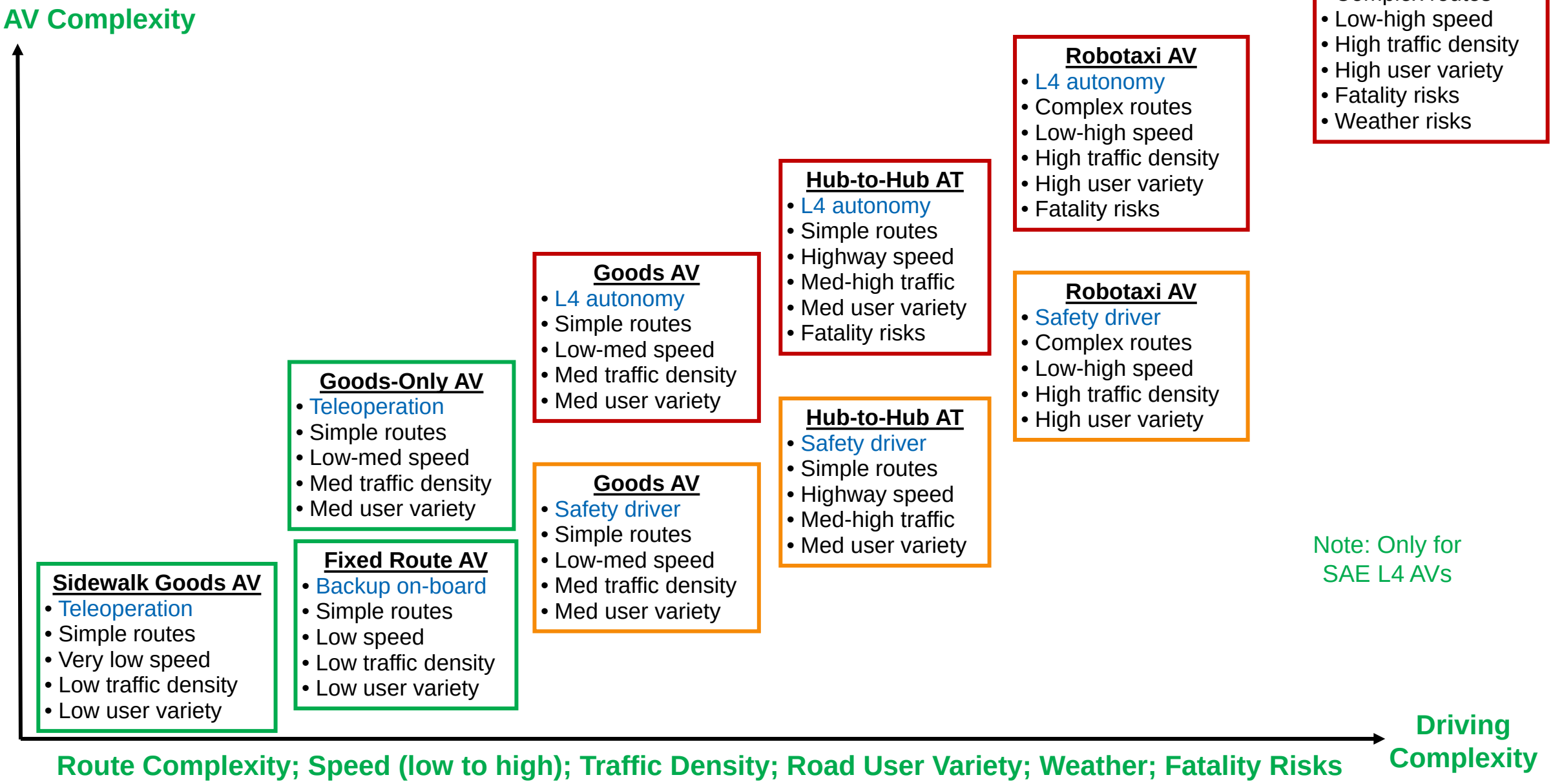
Source: Egil Juliussen; April 2021

Safety: Human Driver vs. AV Software Driver 2 of 2

Issues	Human Driver	AV Software Driver
Weather impact & weather judgement	▶Better than AV, but often over-confident ▶Common problem: drive too fast in fog ▶Driving on flooded roads, etc.	▶Mostly testing fair weather driving ▶Better weather performance expected ▶Judgement: Clear go/no-go in software
Edge cases	▶Advantage! Drivers can handle edge cases ▶Better communication with road users ▶Humans are good at fault mitigation	▶Main current disadvantage ▶Hard to predict pedestrian actions ▶Key to match human driver skills
Crash avoidance & system failure	▶Human driving skill level is key ▶Driver must minimize distractions ▶Driver must not speed ▶Driver must not be impaired	▶AV software driving skill & experience ▶Fail-soft software architecture ▶Hardware redundancy ▶Teleoperation as backup
Future questions & Unintended ADAS consequences	▶Will L1-L2-L3 autos have less crashes? ▶Will L1-L2-L3 autos dull driving skills? ▶Safety impact of senior driver growth	▶How to communicate with road actors? ▶How quickly will edge cases be learned ▶How long are safety drivers needed?
Summary	▶3 issues account for 58% of U.S. crashes: ▶Distraction, speeding & DUI ▶Edge cases are rarely a problem	▶These 3 issues have no impact on crashes by AV software driver ▶Edge case improvements are needed
Edge case: New driving situation or new variations, which is unknown to the AV driver software		

Source: Egil Juliussen; April 2021

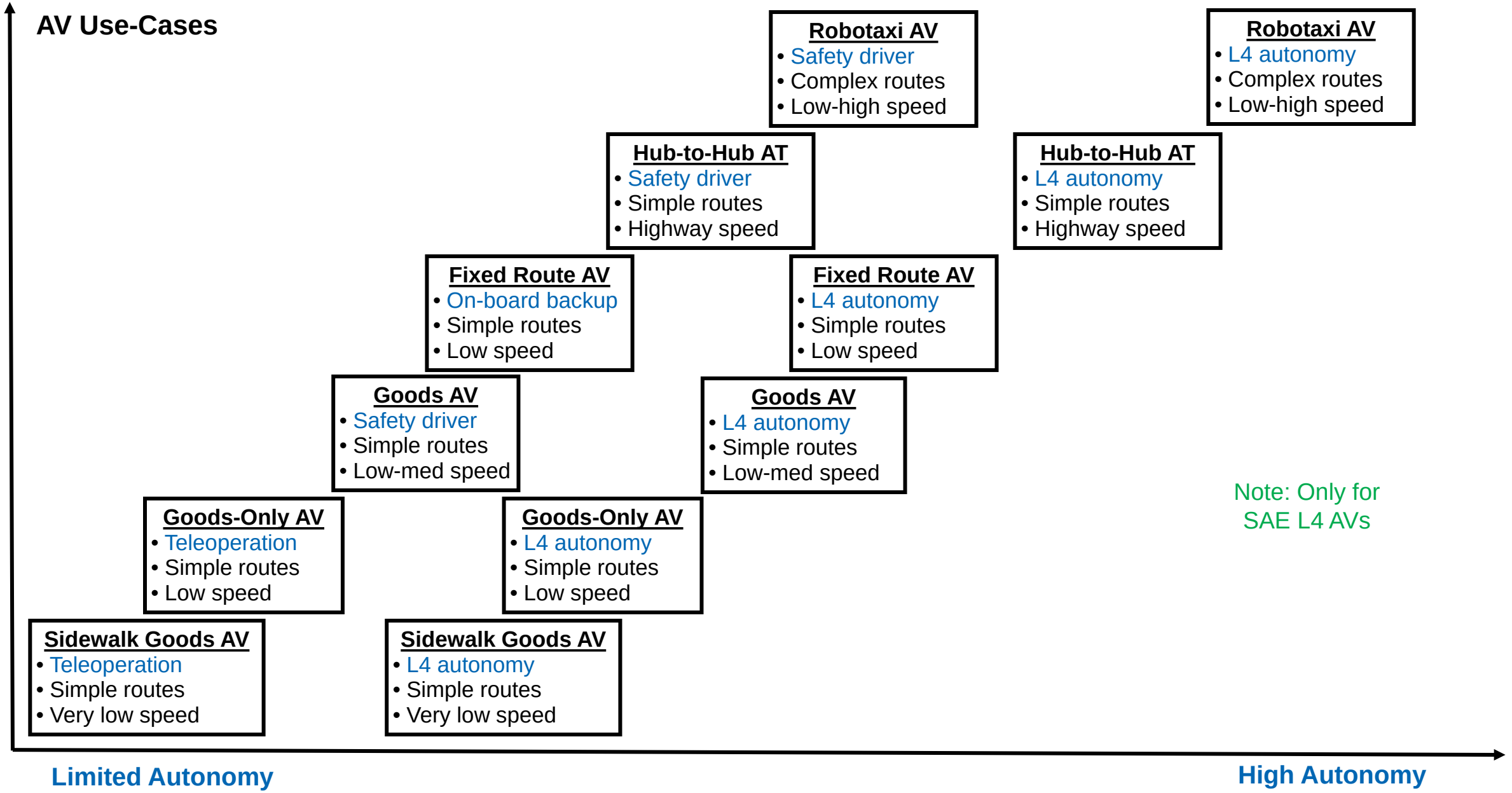
AV Use Cases vs. Complexity



Source: Egil Juliussen; September 2021

AT=Autonomous Truck; AV=Autonomous Vehicle

AV vs. Autonomy Degree



Source: Egil Juliussen; September 2021 AT=Autonomous Truck; AV=Autonomous Vehicle

Autonomous Vehicle Regulation Overview

	Key Information	Other Information
ISO 22737 Low-speed autonomous driving (LSAD)	▸ Low-speed autonomous driving for pre-defined routes ▸ Within specific L4 operational design domains (ODD) ▸ Use-cases: Goods delivery & fixed route AVs ▸ Specifies performance, system & test requirements	▸ Many last mile applications ▸ Likely to have interactions with ITS ▸ Bus routes likely to be popular use-cases ▸ No specification of sensor technology
German AV regulation	▸ Legal framework for AV deployment ▸ L4 use-cases with focus on MaaS ▸ AV operation expected in 2022 ▸ Type Approval required before legal use	▸ Focused only on simplest AV use-cases ▸ Personal AVs are not included yet ▸ Teleoperation is included in AV regulation ▸ Extensive testing required
France AV regulation	▸ Highway Code & Transport Code allows AVs ▸ Legalized complete framework for AV usage ▸ Use-cases are pre-defined routes and zones	▸ Expected to start in September 2022 ▸ Type Approval (homologation) required before use ▸ Similar to ISO 22737 regulation
U.S. AV regulation	▸ NHTSA ADAS L2 & ADS crash data reporting ▸ NHTSA AV proposal released Dec 3, 2020 ▸ “Framework for Automated Driving System Safety”	▸ Started June 29, 2021; lasts 3 years ▸ Written comments ended April 1, 2021 ▸ AV regulation not expected until 2022 or 2023
China AV regulation	▸ March 24, 2021-MPS: Road Traffic Safety Act for AVs ▸ April 7, 2021-MITT: Draft regulation for L3 and L4 ▸ May 2021: AV legislation introduced in Shenzhen ▸ Aug 2021: AV trials for passengers & goods	▸ AV road testing & AV liability included ▸ L5 is not included ▸ Other China regions may follow ▸ For qualified companies; with safety driver
Russia	▸ Allowed AV testing from November 2018 ▸ Release plans for updated AV testing in May 2021 ▸ Yandex is AV leader: robotaxis, sidewalk AVs	▸ Including driverless AVs ▸ No public data available yet ▸ Over 7M AV test miles as of May 2021
Japan	▸ New RTVA & RTA regulation allows L3 ▸ L4 testing is permitted under RTA	▸ Took effect on April 1, 2020 ▸ Japan likely to use ISO 22737 LSAD

Source: Egil Juliussen; September 2021

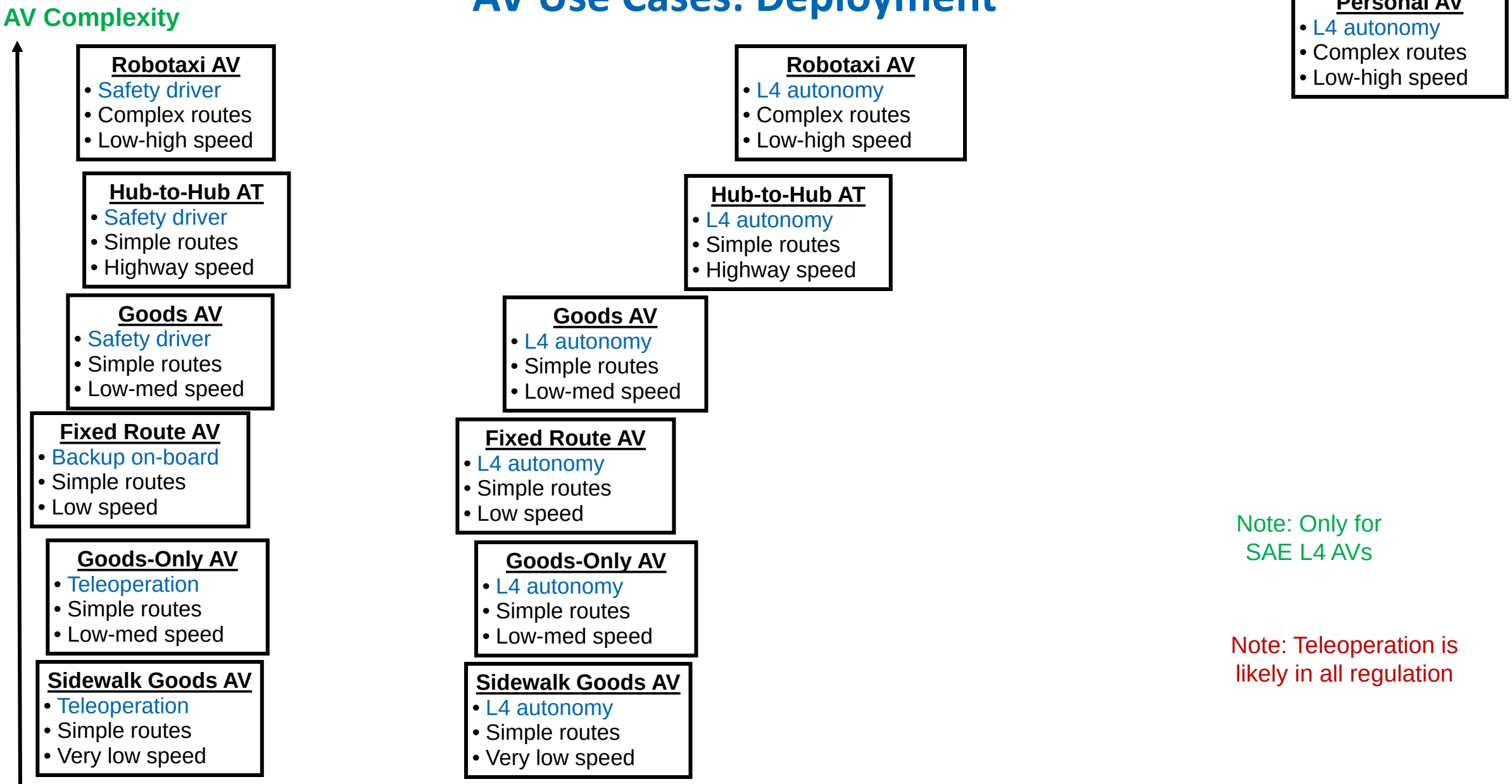
Standards & Regulation Impacting AVs

Standard/ Regulation/Other	Focus
ISO 26262	▸ Functional safety standard ▸ ASIL ratings: A, B, C, D	▸ Safety-critical embedded systems: ADAS ▸ Becoming a standard for processor chips too
UNECE WP.29	▸ Cybersecurity & OTA requirements	▸ Regulation, including type-approval rules
SAE J3101	▸ Hardware-protected security	▸ For propulsion, braking, steering, security, safety
ISO/SAE 21434	▸ Cybersecurity framework	▸ Supported by 26 OEMs & 20 T-1s; Feb 2020 draft
UN WP.29	▸ GRVA/2019/2 cybersecurity	▸ Formal UN standard; may take effect Sep 2020
ISO 21448	▸ Mitigating AV risk due to system failure	▸ Safety of the intended functionality (SOTIF)
IEEE P2846	▸ Decision making for SAE L3-L4-L5	▸ Rule-based mathematical models for AV decisions
IEEE P2851	▸ Interoperability Format, Safety Analysis	▸ Safety Verification of IP, SoC & Mixed Signal ICs
IEEE P1228	▸ Automated-driving–software standard	▸ Limited to safety aspects of AV software
UL 4600	▸ Safety check list for AV designs	▸ Build the safety case for an AV design: L4-L5
SAE & OEMs	▸ Automated Vehicle Safety Consortium	▸ Safety principles for SAE Level 4 and 5
SaFAD	▸ Safety First for Automated Driving	▸ OEM/Tier-1 consortium; White paper on AVs

Source: Egil Juliussen; September 2021

SOTIF=Safety of the Intended Functionality; UL=Underwriters' Lab; UN=United Nations

AV Use Cases: Deployment



Note: Only for SAE L4 AVs

Note: Teleoperation is likely in all regulation

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Questions

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