Chapter Preview

6.1 Autonomous Vehicles
Global 129
US State Policy AV 130
California 131
Safety and Reliability 132
Measurement Questions 134

6.2 Autonomous Weapons 135

Chapter 6: Autonomous Systems

[Table_of_Contents]
[Autonomous_Systems_Technical_Appendix]

Introduction

AI is a key component of Autonomous Systems. This chapter presents data on Autonomous Systems divided in two sections: Autonomous Vehicles (AV's) and Autonomous Weapons (AW's). The AV section shows the countries (AI Index web survey) and cities (Bloomberg Philanthropies) testing AV's. This is followed by US state policy on AV from the National Conference on State Legislation (NCSL). Data from the State of California presents metrics on total AV miles driven and number of companies testing based on the Department of Motor Vehicles (DMV) Disengagement Reports. The results from DMV Collision reports are also analyzed to present safety and reliability metrics related to AVs. The section on AW presents the known types of autonomous weapon deployments and by which country based on expert survey data collected by the Stockholm International Peace Research Institute (SIPRI).

Global

Autonomous Vehicles (AVs) are one of the most visible and potentially disruptive applications of AI. There are prototypes currently being tested around the world. While it is difficult to present a fully comprehensive list of countries where testing is taking place, data from Bloomberg Philanthropy offers insight on the global reach of AV's beyond the United States. The map (Figure 6.1a) below shows at least 25 countries with cities that are testing AV's.

Nordic countries and the Netherlands have made big strides in deploying electric vehicles (EV) charging stations and in using AV's for logistic supply chain management. In cooperation with Germany and Belgium, AV truck platoons will run from Amsterdam to Antwerp and Rotterdam to the Ruhr Valley. Similarly, Singapore has designated test areas in the metropolis for AV's (Figure 6.1b).

World Map of Countries Testing AVs

Source: Online searches on nations testing AV's.

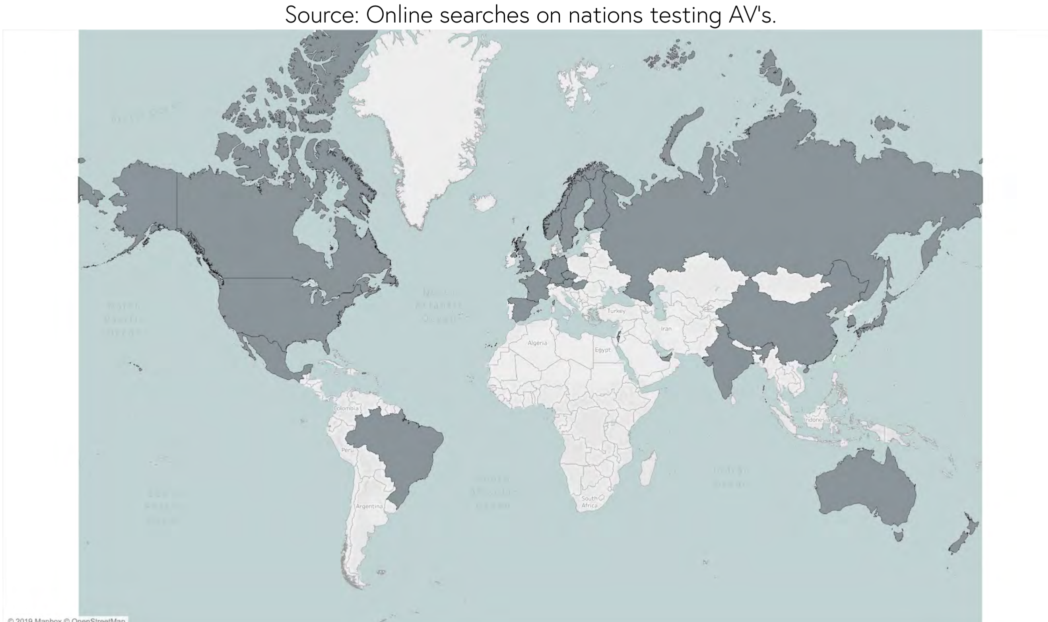

Fig. 6.1a.

Cities Testing Autonomous Vehicles

Source: Bloomberg PhilanthropiesBloomberg Philanthropy, 2019.

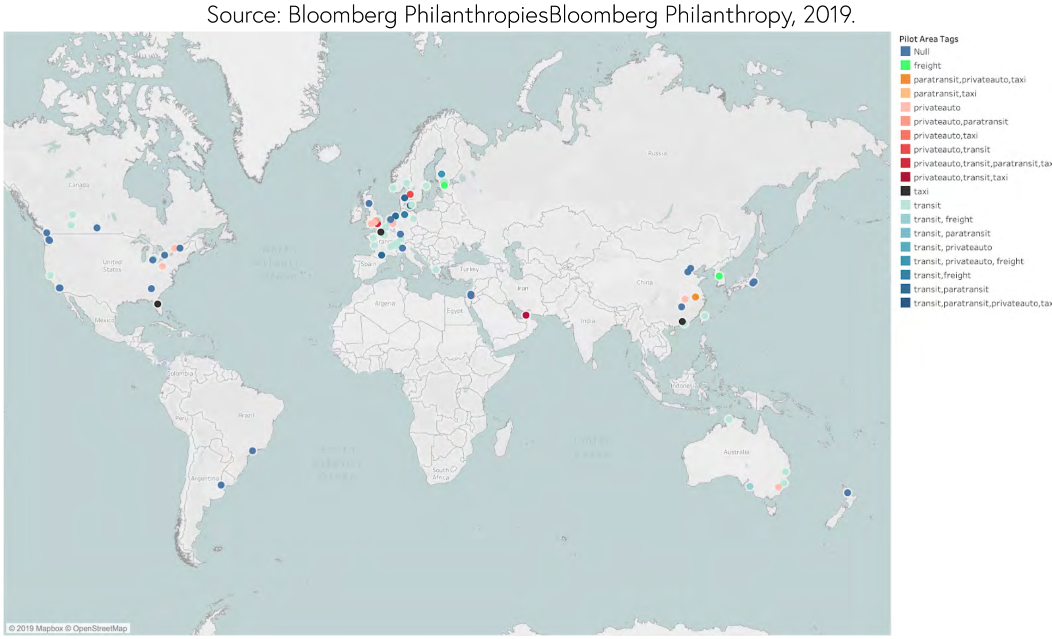

Fig. 6.1b.

US: State Policies for AVs

California was the first state with autonomous vehicle testing regulations. The number of states considering legislation related to autonomous vehicles has been increasing (Figure 6.2). Since 2012, at least 41 states and D.C. have considered legislation related to autonomous vehicles.[21] Ten states authorize full deployment without human operator, including Nevada, Arizona, or Texas, as well as many States on the east coast. Colorado authorized full deployment with a human operator. Many states, such as South Carolina, Kentucky, and Mississippi, already regulate truck platooning.[22]

US State Law on AVs

Source: National Council on State Legislation (NCSL), Governors Highway Safety Association (GHSA), 2019.

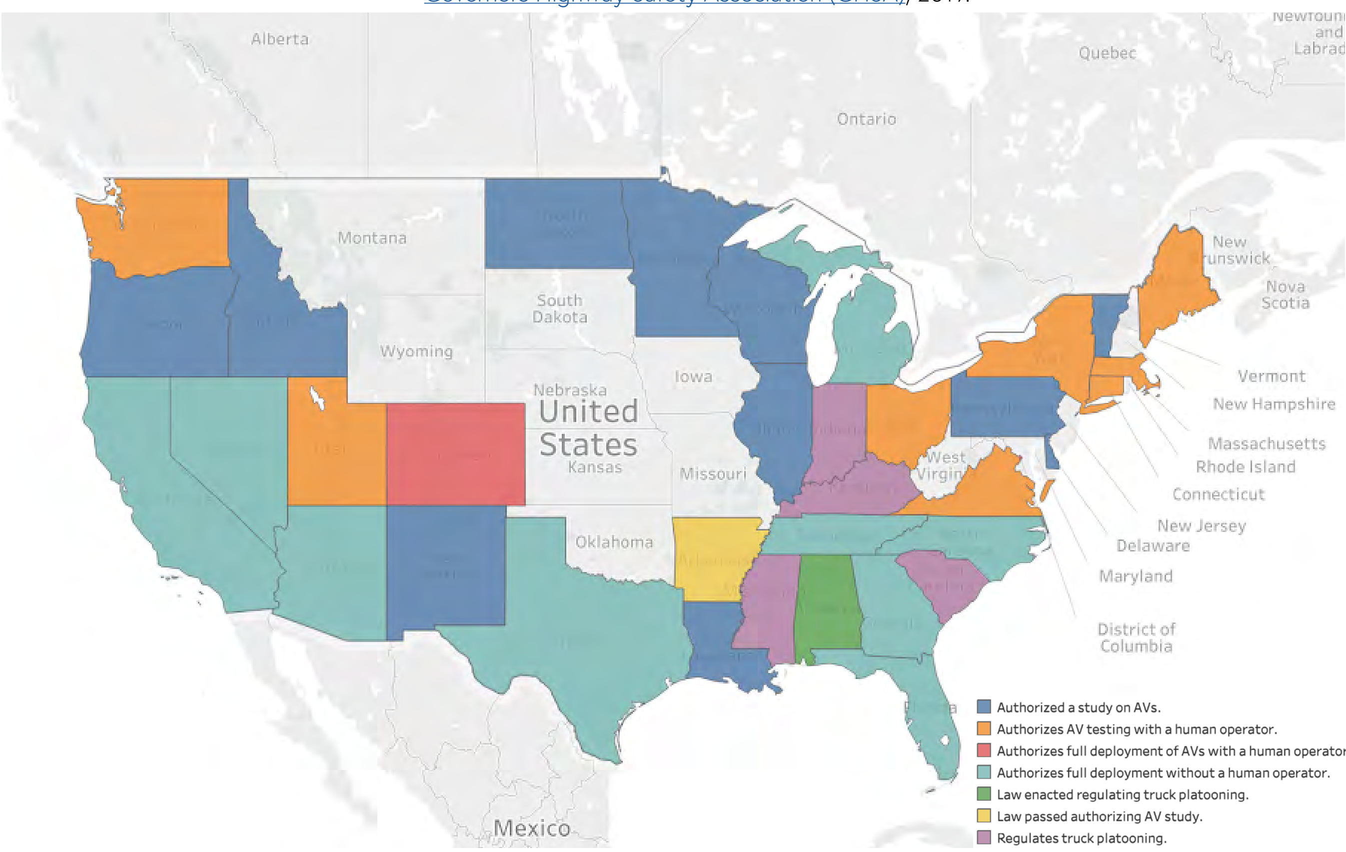

Fig. 6.2.

[21] In 2012, six states, in 2013 nine states and D.C., in 2014 12 states, in 2015 16 states, in 2016 20 states, in 2017 33 states enacted AV related bills. In 2018, 15 states enacted 18 AV related bills. In 2017, 33 states have introduced legislation. In 2016, 20 states introduced legislation. Sixteen states introduced legislation in 2015, up from 12 states in 2014, nine states and D.C. in 2013, and six states in 2012. In total, 29 states have enacted legislation related to autonomous vehicles. Readers can find California DMV Title 13, Division 1, Chapter 1, Article 3.7 –Testing of Autonomous Vehicles which defines the capability and operations that meets the definition of Levels 3, 4, or 5 of the SAE International's Taxonomy and Definitions for Terms Related to Driving Automation Systems.

[22] Truck platooning is the linking of two or more trucks in convoy, using connectivity technology and automated driving support systems. These vehicles automatically maintain a set, close distance between each other when they are connected for certain parts of a journey, for instance on motorways (ACEA, 2019). Multi-brand platooning (up to SAE level 2) with the driver still ready to intervene. By 2023, it should be possible to drive across Europe on motorways (thus crossing national borders) with multi-brand platoons, without needing any specific exemptions. Subsequently, allowing the driver of a trailing truck to rest might come under consideration. Full autonomous trucks will only come later. On 09/2016, NHTSA issued a "Federal Policy for safe testing and deployment of automated vehicles" .

California

In 2018, the State of California licensed testing for over 50 companies and more than 500 AVs, which drove over 2 million miles.[23] Figure 6.3 below shows the number of companies that are testing AV's in California (blue line on the left axis) and the total number of AVs on the road (red line on the right axis). Both metrics grew at an annual compounded growth rate (2015-18) around 90%, increasing sevenfold since 2015. The second chart (Figure 6.4) shows the total number of miles driven and total number of companies testing autonomous vehicles (AVs). This number is calculated by summing the total number of miles driven by individual AV companies, as reported in the Annual DMV Disengagement Reports. 2018 was the year of fastest growth in total miles covered by AVs totaling over 2 million miles. The compounded annual growth (2015-18) for total AV miles driven was 64% growing fourfold since 2015.

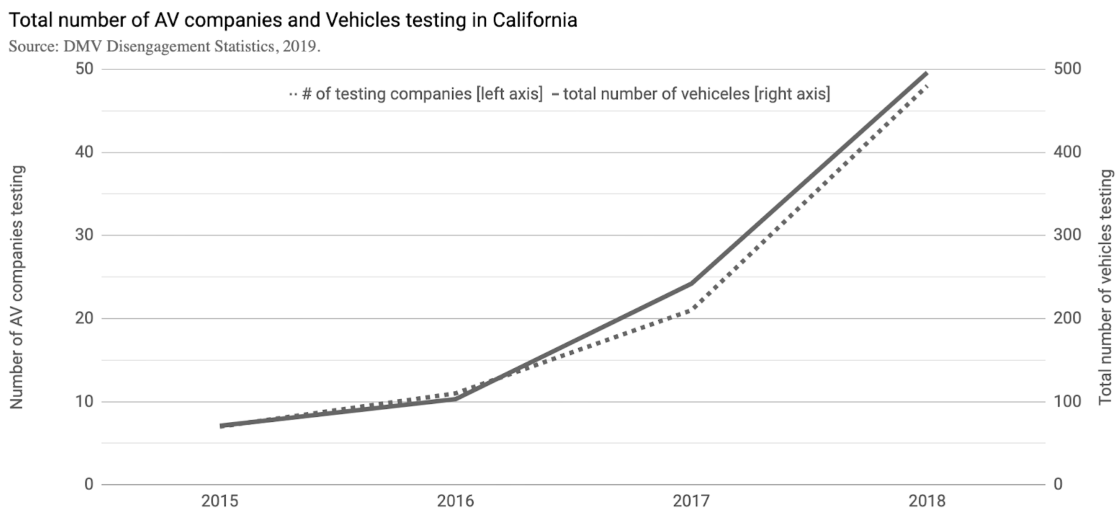

Fig. 6.3.

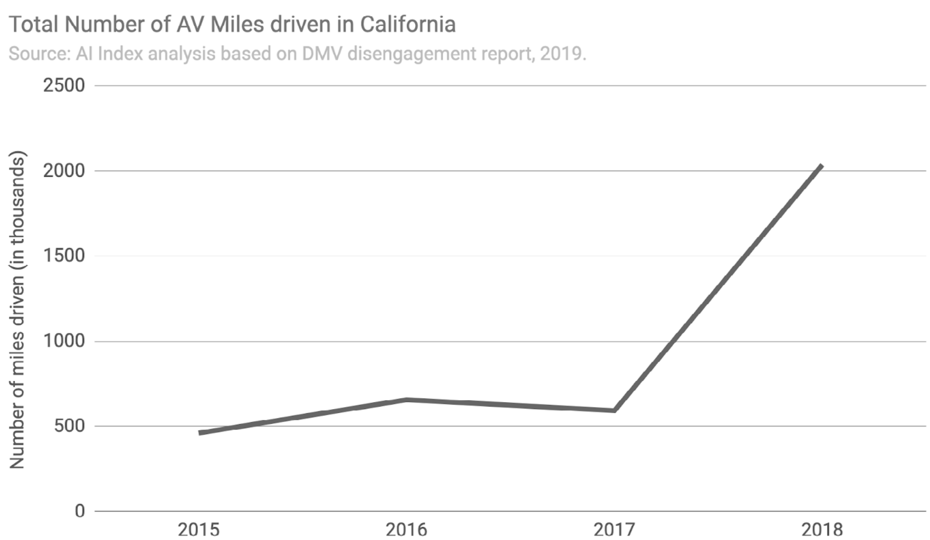

Fig. 6.4.

[23] Effective on September 16, 2014, the autonomous vehicles testing regulations in California require a driver and every autonomous mile, accident, and disengagement to be reported under CA regulation §227.02.

Safety and Reliability

Six times more people have died in traffic related fatalities than the number of fatalities in all wars for the US (Washington Post, 2019). The hope is that AVs can help reduce traffic fatalities in both advanced and developing countries.

Crashes per million miles driven in autonomous mode is the simplest and is the most reliable measure of AV safety (Figure 6.5). In 2018, AV's in CA had 46 crashes coded as being in the autonomous mode in 2018, while driving 2.05 million miles* in the autonomous mode. Or 22.44 crashes per million miles driven. To put this number in perspective below is a table from a 2016 UMTRI report that took an early look at CA AV crash rates. Even adjusting for under-reporting, the 22.44 crashes per million miles for the CA AV fleet is about 5.5x higher than the ADJUSTED rate expected for human-driven vehicles. (see notes on crash rate in Appendix).

In the early stages of development of AV testing, the number of AV related fatalities could be higher than normal traffic fatalities. A higher crash rate may be observed through every mode of automated driving. For example, in 2018 California had 2.05 million AV miles. The point estimate of human driver is at 4.1 (UMTRI) the expected crashes for AV is 8.4 with actual AV crashes in California of 46.

The pie charts summarize the Collision Report of the DMV. In most of the accidents, a car driven in the daytime by a human rear ends an AV that is either stopped or going straight. Studies suggest that these are caused by unexpected behavior by the AV or error by the human driver. Most damages have been minor.

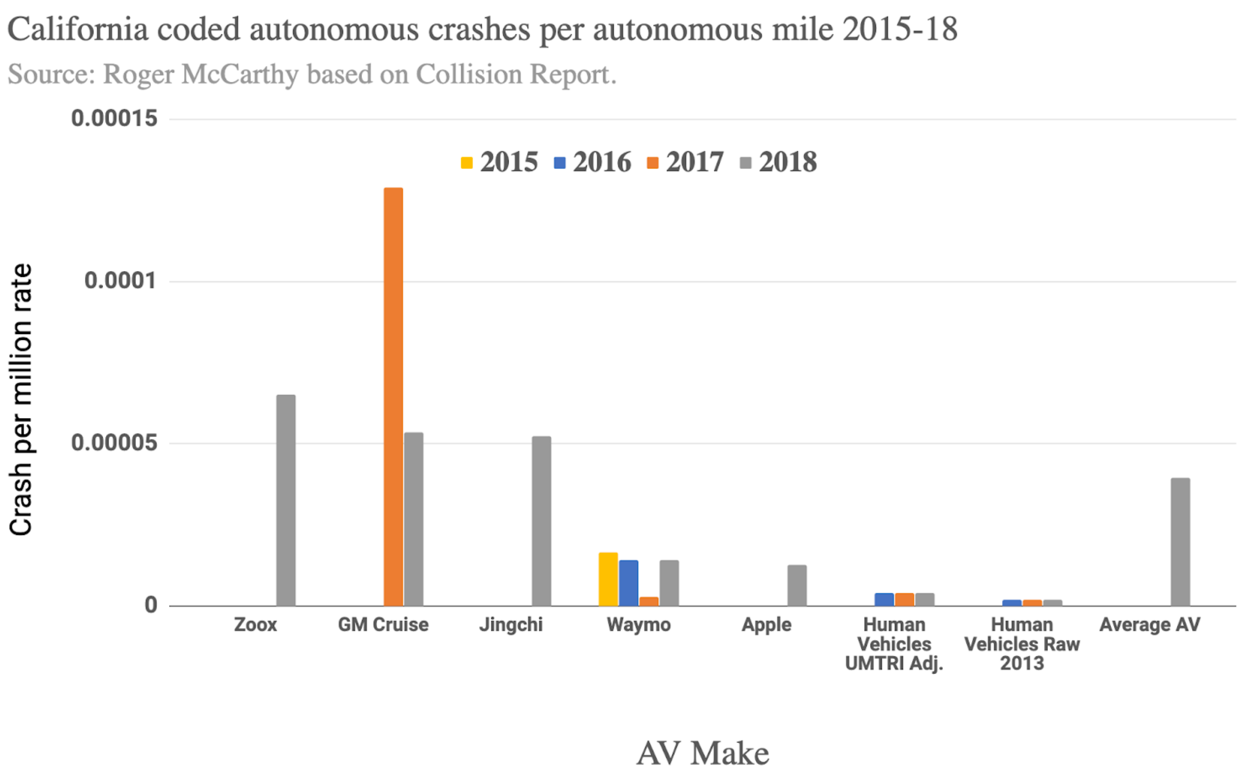

Fig. 6.5.

"I believe the 2018 AV crash rate is an underestimate of the true crash rate, and I expect the AV crash rate to continue rising. The calculated 22.4 2018 crash rate is based on the OL 316 crash form coding, which doesn't capture the effect of the AV driver turning off the AV mode moments before a crash. I believe more accurate coding would move additional crashes into the "autonomous" category. Secondly, AV's are driven, and have their crashes, under virtually ideal daytime driving conditions. When AV's are finally tested in more adverse environments of rain, snow, and fog, I am sure the AV crash performance will degrade, as with human drivers. The technical challenges of keeping sensors clean and operational under such conditions remain."
Roger McCarthy, Principal, McCarthy Engineering

Safety and Reliability

Summary of Collision Report for Autonomous Vehicles in California, 2018

Source: DMV Collision Reports, 2019.

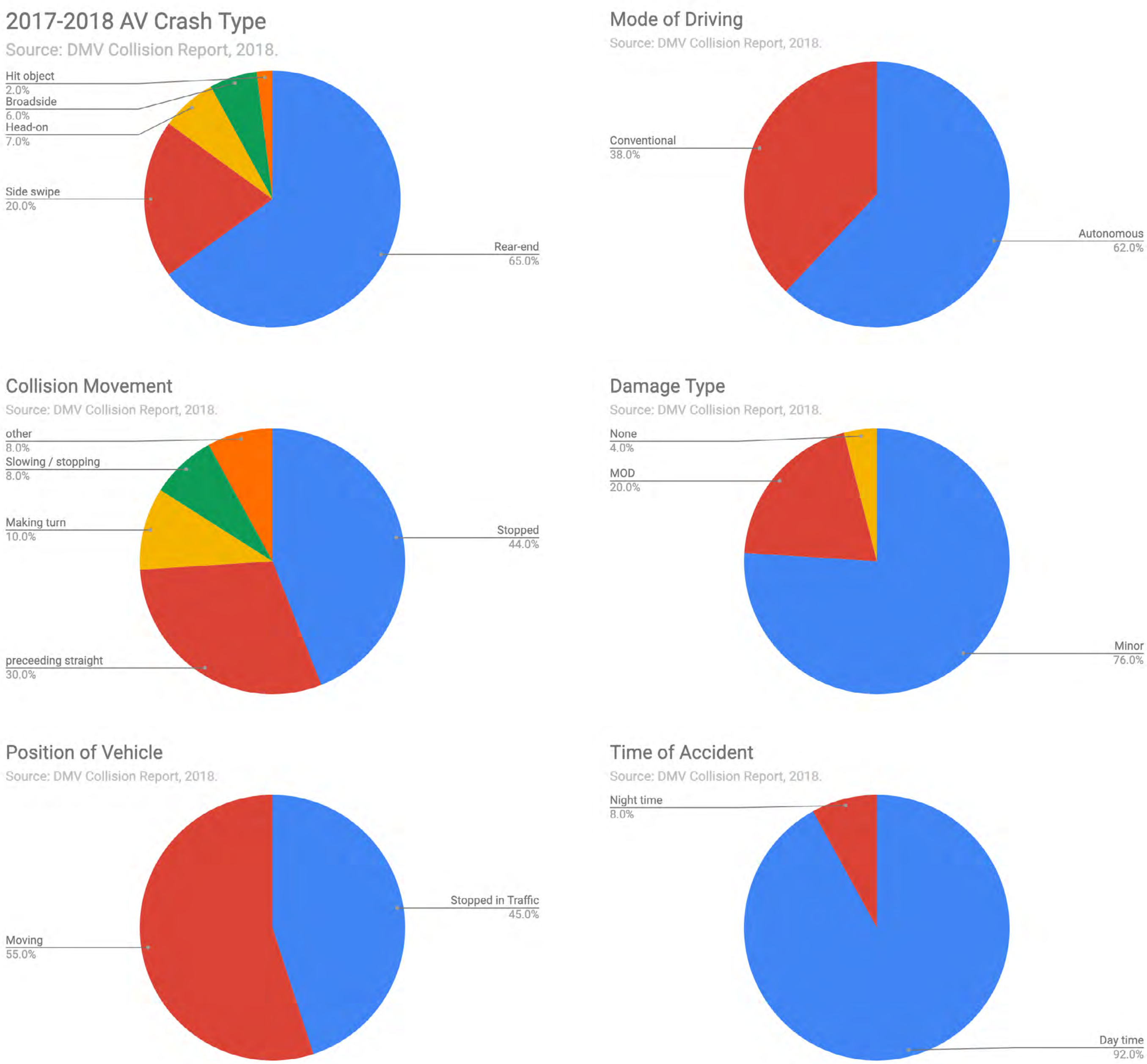

Fig. 6.6.

Measurement Questions

- The data uncertainties related to disengagement reports are well-known. Improvement in fine-grained data collection and intrinsic reporting from AV companies is critical, as is understanding which are the identifiable AI components in AV systems. The failure and incidents report of AV-AI components is industry sensitive information, which nevertheless requires standardized measurement, reporting, and identification of reliability metrics. In particular, diverse approaches to reporting even when using the same measure (for example, disengagement) highlights challenges in standardization. Further, measurement practices from companies could be associated with self-selection bias that accentuate the positive and share selectively (voluntary safety self assessment).

- Risk-informed performance-based approaches could characterize all uncertainties including engineering ones into the operation, policy and regulation of AVs. Adoption of probabilistic risk analysis from other complex engineering domains could help empower innovation and lead to better design, adequate safety features and sound policy (see Summary and Presentation Slides from: Workshop on Risk Analysis for Autonomous Vehicles: Issues and Future Directions).

Autonomous Weapons

Autonomous Weapons (AW) include various systems for either defensive or offensive capabilities. For example, Automated Target Recognition (ATR) systems autonomously acquire targets and have been in existence since the 1970s. Existing systems are largely defensive in nature with humans determining the decisions surrounding the time, location, and category of targets. A recent survey found that at least 89 countries have automatic air defense systems in their arsenal and 63 countries deployed more than one type of air defense system. Active Protection (AP) systems are developed and manufactured by only nine known producing countries. The charts below show the total known number of AW systems known to be deployed globally according to expert-curated data from the Stockholm International Peace Research Institute (SIPRI) (Figure 6.7a). The total number are classified into three labels: combative for military purpose with more than targeting capabilities i.e. machine makes the execution decision, systems with targeting capabilities only, and systems designed for intelligence, reconnaissance, and surveillance purposes including logistics, EODs, etc.. called others. A SIPRI report on [Mapping the Development of Autonomy in Weapon Systems] provides a detailed survey of AW systems. The total number of known AW systems by countries is presented between 1950-2017 (Figure 6.7b).

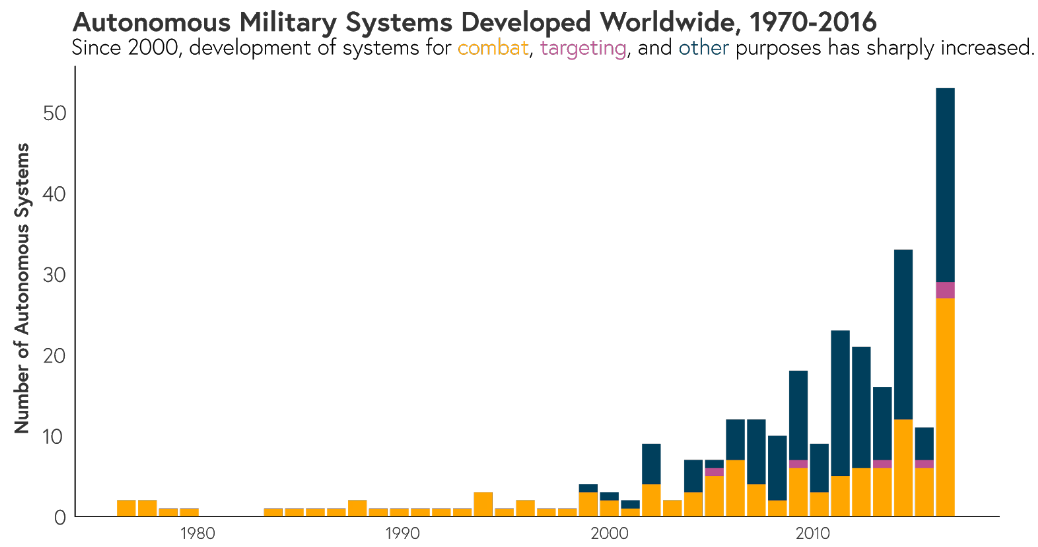

Fig. 6.7a.

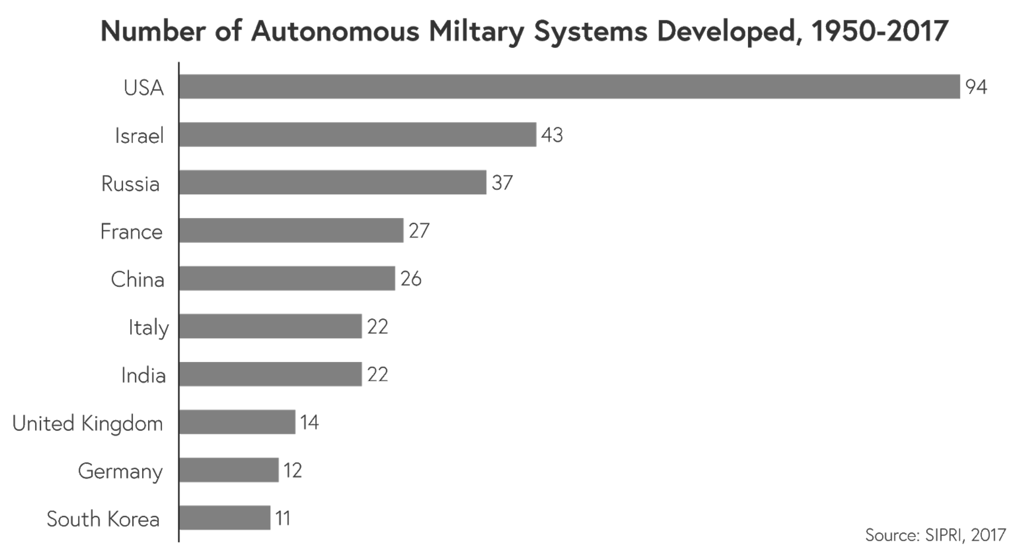

Fig. 6.7b.