2019

RoboCar Progress Report

Preface

CityTram is primarily interested in effective public transportation – fast, cheap, reliable, safe, and environmentally sensitive. For several years now the development of autonomous vehicle technology has been anticipated by the public transit community as the coming answer to all those needs. While we doubt that is true, we are still interested. As veterans of Silicon Valley, we recognize that most of what is known by most people about this coming technology is the product of the hype machine, and is not to be trusted. So we have invested our time and energy to monitor what little hard factual data can be obtained by the public, as a way to objectively evaluate the status of the technology. Each year we publish these findings.

In 2019, according to the Governor's Highway Association (www.ghsa.org/state-laws/issues/autonomous%20vehicles) 13 states had open AV studies, while 24 states had legislation authorizing some form of AV testing or deployment: 5 authorized truck platooning; 8 authorized on road testing; 11 authorized deployment. Twelve states have authorized level 4 on road testing (no human monitor). A number of companies are developing autonomous vehicles. On road testing of those vehicles was actually occurring in at least 6 states: Arizona, California, Florida, Nevada, Pennsylvania, and Texas. Some companies test only in California. Some test only in other states. Some test both in California and in other states. This document reports ONLY on the status of companies that tested in California, and it ONLY reports about the testing done in that state, because California is the ONLY state that has enacted responsible test reporting requirements. These requirements make objective test data available to the public at this link (https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/testing).

Many people complain that the minimal data reported presents a distorted view of the development reality. We acknowledge it is limited, and can in cases easily be miss-interpreted. But its unfortunately all we have, so we attempt to put it to meaninful use.

65 such companies held test permits in California as of January 2020. Not all of them are actually testing. Some are testing advanced ADAS (automation level 2) capabilities. Some are testing on private tracks, parking lots, or other such facilities. This document reports only on those actively testing, on public roads, at automation level 3 or higher. As the number of companies who are actively testing has increased this year, we have raised our reporting threshold. We only report on companies who reported 5,000 miles or more of testing this year, or who have accumulated at least 10,000 miles in this and previous years. As such the following companies' results are not covered: Nullway, NVIDIA, Qualcomm, SF Motors, Telenav, Tesla, Toyota Research Institute, Udelv, Valeo North, SAIC Innovations, Phantom AI, and Plus AI. Additionally, AiPod, which was covered in prior years did not report any testing this year, and was not covered.

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Basic Lingo Explained

If you are new to the technology, and its vocabulary, this should help.

Disengagement:

Imagine you are teaching your teen aged child to drive. Your child has passed the first tests, and has a learner's permit permitting him/her to drive, during the day, as long as accompanied and monitored by an adult fully licensed driver. So you climb into the passenger seat and the two of you head out to drive through your local community. Everything is going fine for awhile. Then, as you drive past a local mini-mall, a car with a mattress strapped to the roof pulls out of the parking a little too tight in front of you. Rather than lifting off of the gas pedal, or lightly applying the brakes, your child instead lets out a blood-curdling scream, pushes back in the seat, and takes both hands off the steering wheel and presses them against the roof for bracing. Something about the mattress confused your child too much. The vehicle is no longer being controlled.

THAT is a disengagement ! You reach across and grab the wheel, quickly slide over to get close, and swing your left leg over to reach the brake pedal with your foot.

An AV has various sensors that permit it to see the world around it: cameras, lidar, radar, ultrasound, etc. Its perception system allows it to take the input from all those sensors and create a model of the world around the car. Just like you, its perception system has certain sanity checks built in. If you walked into your living room and instead of seeing the lamp sitting vertically on the end table, you saw it sticking horizontally out of a wall, you would know something was wrong. Your perception doesn't make sense. First, the lamp is not where you expect it to be. And second, it is not behaving consistent with gravity as you understand it. So the AV is smart enough to know when it is hopelessly confused. It is also programmed to recognize certain threats, like a pedestrian walking into the roadway in front of you. But it may not be programmed with how to respond (slam on the brakes) for all threats. So, any time the AV is confused or does not know what to do, it throws up its hands and screams. It disengages. An alarm goes off inside the car, which alerts the "monitor" to take control of the car. That is why level 3 vehicles require a monitor (emergency response driver) to be behind the wheel at all times, and ready to take control.

Autonomous Mode vs Manual Mode vs Observer Mode

An AV equipped car can be operated just like a normal car, with a person driving it and the computerized "driver" turned off. This is called "manual mode", or sometimes "conventional mode". Alternatively the computerized driver can be given control of the vehicle. This is called "autonomous mode". Some vehicles are capable of a third mode, called "observer mode". In observer mode a person drives the car, but the computerized driver is on and observes the human driver's actions in order to "learn".

A quick techie diversion into “learn”. To date all AVs employ some artificial intelligence (AI), usually in the form of a neural network. Neural networks are electronic systems that mimic the structure of the human brain. These networks can be “trained” to capture “knowledge”, without “understanding”. Training is basically a curve fitting process in a high dimensional continuous space. So trained networks can act like memory for highly complex associations – if you see this set of sensor inputs, then execute this set of vehicle control actions. So “form habits” might have been a better phrase than “learn”.

Route Planning, Mapping, and Geo-Fencing

One of the functions an AV driver must perform is deciding where to go – which lane, which turn, etc. This is called “route planning”. Route planning must occur within the context of a map of the area. This is typically a more detailed map than you might observe on-line at Google Maps or Open Street Maps. One of the main purposes of observer mode (and there is usually an observer function running in the background in autonomous mode) is to collect sensor and perception data to create these detailed maps. There are also separate companies whose whole business is the production of these maps.

In theory, availability of these detailed maps for an area permits the AV to do a better job of driving in that area. So the AV needs to know when it is in an area for which it has the map data. In fact some AVs can be programmed to only drive in these areas. This is called geo-fencing the AV.

Levels 3, 4, and 5

Level 3 automation is the first (lowest) level where the AV driver is capable of completely driving the vehicle. It may however fail or disengage at any time, and so a human emergency driver is required to “monitor” driving operations at all times, and be ready to assume control immediately upon notice (while the vehicle is in motion).

Level 4 automation is where the AV driver is capable of completely driving the vehicle, under specified circumstances and in a specified area. It is also capable of monitoring for the presence of those circumstances and location within that area, and of performing an orderly “hand-over” (disengagement). So for example, a vehicle capable of freeway driving in good weather in California could be switched into AV mode on the entrance ramp. It would drive completely independently along the freeway, while the human sleeps, reads, or whatever. At the destination the vehicle would drive down the exit ramp, pull off to the side of the road, stop, and alert the human that it was no longer capable of proceeding further. If at any time along the route it started to rain, the vehicle would likewise slow down to be safe, find a place to pull over, stop, and alert the human that it could no longer proceed.

Level 5 (the holy grail) automation is fully capable of driving independently anywhere under any conditions.

2019 Executive Summary

There was in excess of 2.8M miles of AV testing on California roads in 2019. Only Waymo is authorized for level 4 testing. Zoox, Waymo, Pony.AI, AutoX, and (just last month) GM Cruise, are authorized to carry passengers in level 3 operation, but not for revenue. All other companies are authorized for level 3 testing only. Despite Zoox operating this service the longest, Waymo has accumulated the most ride-hail experience, about 30K rides, with all others at around 200 rides each.

A contingent of Chinese companies arrived on the CA scene this year in a big way. Baidu, who had accumulated less than 20K test miles in previous years, added almost 110K miles this year. Pony.AI, a silicon valley startup founded by 2 Chinese immigrants who previously worked for Baidu America, had previously focused on testing and a public service in Guangzhou, China. This year they operated ride-hailing in Irvine, CA, and achieved 174K miles of testing. Hong Kong and Shenzen based AutoX added testing and ride-hailing in silicon valley to that they were already doing in Shenzen and Shanghai. But not all Chinese efforts made progress. Testing by Jingchi WeRide dropped off significantly, with rather poor technical results.

Press coverage remained measurably more negative than in the “hype years”, with regular reports of poor performance (ex. “Hackers stuck 2-inch strip of tape on a 35-mph speed sign and successfully tricked 2 Teslas into accelerating to 85 mph”). The NTSB formally attributed Tesla as partially to blame for 2 of its fatal AutoPilot crashes. Gartner maintained the technology in the “trough of disillusionment” stage. The calls from industry insiders for more stringent regulations and oversight from government grew much louder. But Uncle Sam is not listening. Elaine Chou’s US DOT updated its ADS spec again, to version 4.0 this year, still without anything stronger than “guidelines”.

So industry itself is picking up the regulatory and standardization slack. IEEE formed 3 working groups: P2846 (“formal model for safety consideration in automated vehicle decision-making.”); P2851 (“data format for safety verification of electronics”); and P1228 (“AV software safety”). Underwritters Lab moved UL 4600 “Comprehensive Safety Standard for Autonomous Products” to ballot. A consensus also formed around using ISO/PAS 21448 “safety of the intended functionality”, in addition to ISO 26262 “risk mitigation in the presence of failure”. The Automated Vehicle Safety Consortium was formed, with SAE International, Ford, General Motors (GM), Toyota, and Uber as founding members. (DESIGNLINE<https://www.eetimes.com/designline/automotive-designline/>)

It was a pretty dynamic year in terms of technology leadership. It appears we now have 4 groups: results, experience, promise, and immature. The chinese newcomers Baidu and Pony.AI arguably have better results than the perennial leader Waymo. But their experience level is still quantitatively so small that judgment is not reliable. Meanwhile Waymo and GM/Cruise continue to show good results while extending their lead in experience. Zoox, Nuro, and AutoX show great promise in their results, but don’t yet match the leaders, and fall further behind in experience growth. Meanwhile a cluster of others,

including some big names like Apple, Lyft, Mercedes Benz, Nissan, and Uber, really cannot yet show a credible offering.

Fourteen (14) companies appear in the positioning graph below. Basically what we seek is an AV driver that is reliable, safe, and has enough experience to be trusted. Reliability is represented in the graph by the average interval between disengagements, on the X-axis. Safety is represented by the average interval between accidents, on the Y-axis. So progress is represented by moving up and to the right. The bubble size represents the total accumulated on-road test mileage, and so is an indication of experience. On October 31, 2018 Waymo became the first company to be authorized by the state of California for level 4 on road testing. It remains the only such company. This is indicated by the bubble color.

Pony.AI had about 12% as many test miles as Waymo this year. It was the 3rd largest tester, with about 6% of all test miles. The disengagement interval is about half that of Waymo and Cruise, or about once every 6 months. It only had 1 reported accident. These results make it reasonably reliable and more than twice as safe as Waymo. But a single incident would change those quantitative results significantly. There is just not yet a sufficient level of experience to know for sure.

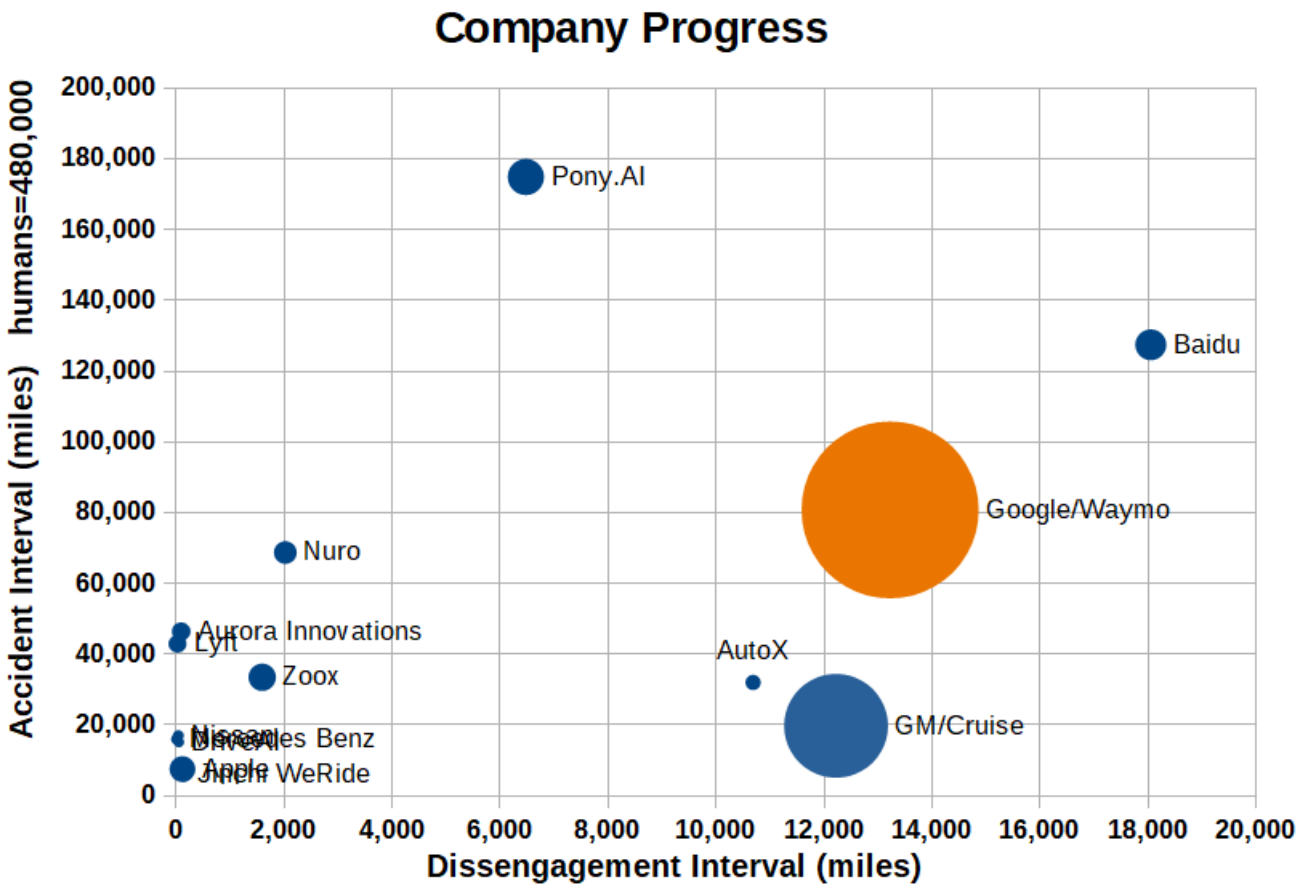


Figure 1: Positioning Graph

Similarly, Baidu now exhibits both a disengagement interval and an accident interval about 50% better than Waymo. But Baidu had no accidents and only 4% of all test miles. So we just don't know yet if that level of performance can and will be maintained.

Waymo increased its testing mileage about another 10% this year, accounting for 51% of all test miles. It improved its disengagement interval another 20% (about once per year per vehicle). It is not clear how much of that CA mileage is in level 4 operation vs level 3. The accident interval was stretched about 33%, so the Waymo driver is now only about 6 times more accident prone than human drivers.

GM/Cruise doubled its test mileage this year, and accounted for 29% of all testing. It has now effectively closed the gap with Waymo regarding disengagements. The disengagement interval is now in excess of a year's worth of average driving. But its accident rate actually ticked up slightly, and is about 4 times that of Waymo. It has the worst accident rate of the top 7 players.

AutoX has headquarters in Hong Kong and Shenzen, and R&D operations in Beijing, Shanghai, San Diego, and Silicon Valley. This was the first year of California testing, but they did receive a California permit for ride-hailing operation. The technology appears to be relatively reliable, with only 3 disengagements in 32K miles of operation (< 1% of all test miles). It had no reported accidents. So that puts it just (10%) behind Cruise with respect to disengagements, and 50% ahead of them with respect to accident interval. But again, the sample size is just too small to know if this is a valid measure.

Zoox was able to put its corporate infighting behind it and continue its progress in 2019. It more than doubled its test mileage. But its disengagement interval dropped about 25% (about once every 6 weeks). Their safety record remains credible, and their accident rate cut in half this year. Different than other players, Zoox is a vertical play, with their own custom vehicle and software stack. They made significant progress in vehicle design/manufacture this year by achieving NTSB crash safety certification. Still their AV development continues to lag due to lack of resources. They continue to look like a probable acquisition target, more than a probable successful independent effort.

Nuro jumped onto the scene this year with decent disengagement rates and good accident rates. Nuro is a robotic package delivery solution, so its not clear what vehicles are undergoing testing, nor under what conditions. One would expect small low speed delivery vehicles to have good safety performance. No accidents were reported, and only limited test miles (again expected for a low speed only solution).

Apple's on-again, off-again effort was essentially back off in 2019, with most of their vehicles idle and only 10% of the test miles they had the year before. It appears they did accomplish a 100x improvement in disengagements, now at just over 100 miles (approximately once every two days). They are just not credible.

Aurora Innovations and DriveAI both use AI for drive control as well as for perception. They are using a different approach, that uses observer mode to learn from human drivers. They restrict the roads chosen for testing in a way that gradually increases the degree of challenge. This is expected to keep the disengagement interval low for a longer time. This approach does not appear to have borne fruit in 2019. They are falling further behind and are not serious contenders today.

Editorial Comment

For years the AV industry has been “selling futures”. They decry the current fact of 40K annual deaths from driving, describe a beautiful fantasy future where AVs will avoid that carnage, and claim the safety benefit for their technology now. The facts reveal that as a LIE! It is a legitimate question if the technology will ever be able to achieve that lofty ambition, and even industry insiders such as the Waymo CEO now admit that. The expected time horizon for even approaching that goal has pushed out 5 to 10 years in the past 18 months (since the Uber fatality and multiple Tesla fatalities). It is still a worthy goal to pursue. But there is NO question the current state of the technology falls short of this ambition.

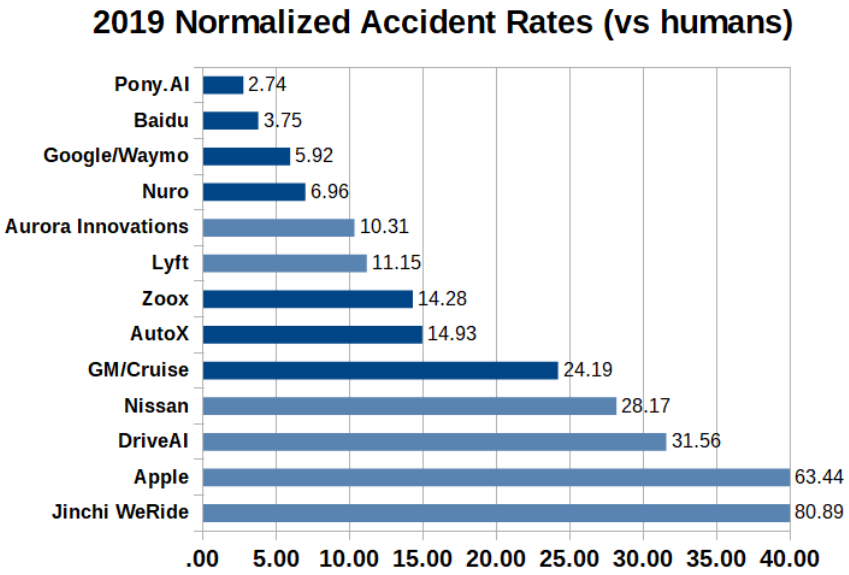


Figure 2: A Promise NOT Yet Kept

The ONLY publicly available data we have – from the state of California – show the facts. Driving on the same roads as humans (even though only in the best conditions), the machines are still multiple times more accident prone than humans driving in all conditions (snow, ice, rain, fog, etc).

And yet, 11 states have authorized full deployment of AVs on public roads, including at level 4 (no safety driver), with many states (such as Florida) requiring absolutely no certification or demonstration of capability. AVs have been legally authorized to hunt humans. Whether deaths will result is not a question. The only questions remaining are how many, and who.

Four companies are in ride-hailing service in California, at least one in Arizona, one in Texas, and one in Florida. As revenues from these grow, the pressure on other companies to accelerate deployment grows. This pressure is independent from the readiness for such deployment. This will naturally lead to greater

risk taking. With no regulatory barrier or criteria in place to limit choices, this risk taking is very likely to result in public harm.

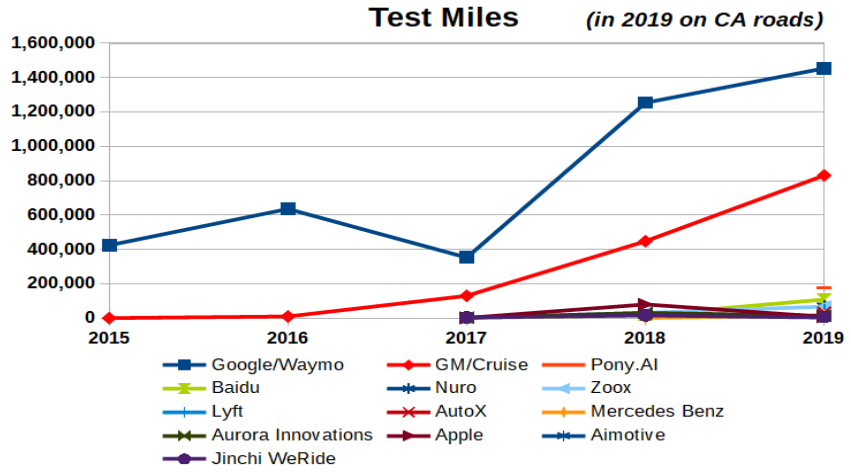
Several years ago we identified what we thought might be a testing hole. Specifically we theorized that when multiple AVs were in close proximity, their LIDAR systems might interfere with one another, creating perception errors. Finally our concern is not just being responded to, but it is being acknowledged as a legitimate problem. Note from a TechCrunch article describing one vendor's technology, "It is an emerging concern that lidar systems of a type could inadvertently send or reflect beams into one another, producing noise and hindering normal operation." (www.techcrunch.com/2020/01/17/barajas-unique-and-ingenious-take-on-lidar-shines-in-a-crowded-industry/)

There is still a ways to go, but the industry is working through the needed steps for this engineering project. The first generation of lower cost lidar systems are just now becoming available, and second generation (different wavelength, longer range) lidar is on its way. The Tesla AV control board is the first known example of a redundant ISO safety standard (26262) compliant control system including AI (neural network) components. Most other competitors are not yet there. Industry standard test and validation methodologies are not yet in place, although (as mentioned in the Executive Summary) definition of such standards is now in progress. But architectures, software, and AI in particular remain the great risks. Many neural network forms are known to exhibit "catastrophic collapse" in rare (and as yet uncharacterized) corner cases. System architectures do not yet address "suddenly going blind". IMHO, the science of AI is not yet well enough developed for mass scale deployment and use in mission critical applications.

Test Results

Test Miles in 2019:

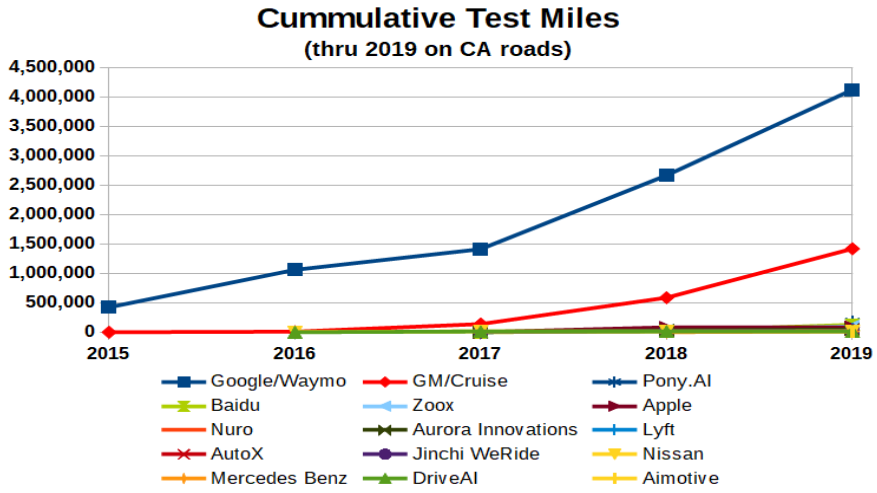
Test miles by Waymo and GM/Cruise far exceeded those by other companies.



Test Miles (on CA roads)	2015	2016	2017	2018	2019	
total	**424,570**	**650,280**	**503,274**	**1,888,632**	**2,833,038**	**100%**
Google/Waymo	424,331	635,868	352,545	1,254,117	1,454,491	51%
GM/Cruise	239	9,756	129,764	447,681	831,040	29%
Nissan		4,099	5,007	5,473	2,412	0%
DriveAI		557	6,015	4,617	3,974	0%
Apple			838	79,845	7,544	0%
Zoox			2,244	30,764	67,015	2%
Aurora Innovations			2,397	30,618	13,429	0%
Baidu			1,072	18,093	108,300	4%
Jinchi WeRide			3,392	15,675	5,917	0%
Mercedes Benz				1,749	14,238	1%
Aimotive					6,056	0%
AutoX					32,054	1%
Lyft					42,931	2%
Pony.AI					174,875	6%
Nuro					68,762	2%

Cumulative Test Miles:

Accumulated test experience (miles) by Waymo and GM/Cruise far exceed those by other companies.



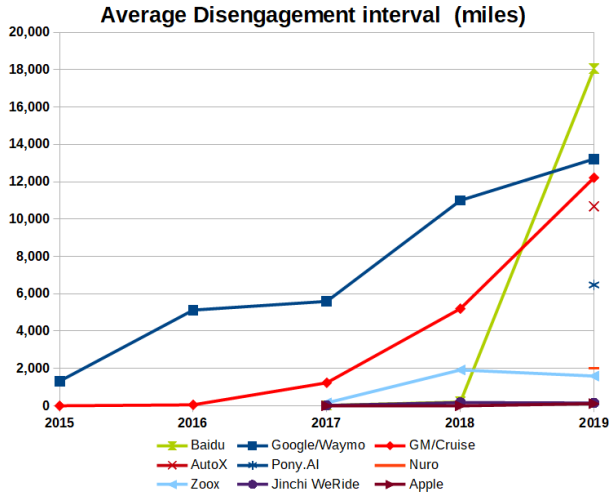
Cumulative Test Miles	2015	2016	2017	2018	2019
Google/Waymo	424,331	1,060,199	1,412,744	2,666,861	4,121,352
GM/Cruise	239	9,995	139,759	587,440	1,418,480
Nissan		4,099	9,106	14,579	16,991
DriveAI		557	6,572	11,189	15,163
Apple			838	80,683	88,227
Zoox			2,244	33,008	100,023
Aurora Innovations			2,397	33,015	46,444
Baidu			1,072	19,165	127,465
Jinchi WeRide			3,392	19,067	24,984
Mercedes Benz				1,749	15,987
Aimotive					6,056
AutoX					32,054
Lyft					42,931
Pony.AI					174,875
Nuro					68,762

Disengagements Reported 2019

These counts were reported for the year. When combined with the annual test mileage, interval data is produced.

Disengagements	2015	2016	2017	2018	2019
Google/Waymo	321	124	63	114	110
GM/Cruise	103	181	105	86	68
Nissan		28	24	26	58
DriveAI		58	93	55	75
Apple			7074	69510	64
Zoox			14	16	42
Aurora Innovations			130	308	141
Baidu			48	88	6
Jinchi WeRide			162	89	39
Mercedes Benz				1194	2054
Aimotive					26
AutoX					3
Lyft					1667
Pony.AI					27
Nuro					34

Avg Disengagement Interval	2015	2016	2017	2018	2019
Google/Waymo	1,322	5,128	5,596	11,001	13,223
GM/Cruise	2	54	1,236	5,206	12,221
Nissan		146	209	211	42
DriveAI		10	65	84	53
Apple			0	1	118
Zoox			160	1,923	1,596
Aurora Innovations			18	99	95
Baidu			22	206	18,050
Jinchi WeRide			21	176	152
Mercedes Benz				1	7
Aimotive					233
AutoX					10,685
Lyft					26
Pony.AI					6,477
Nuro					2,022

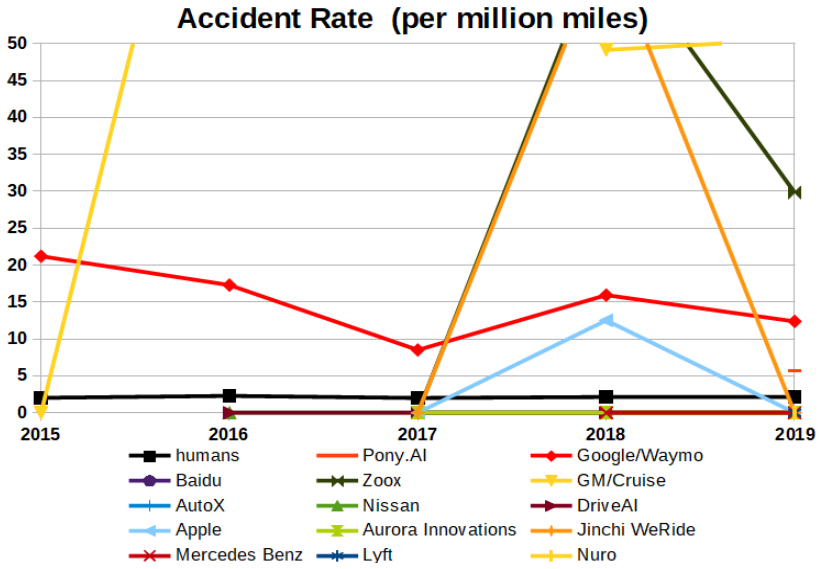


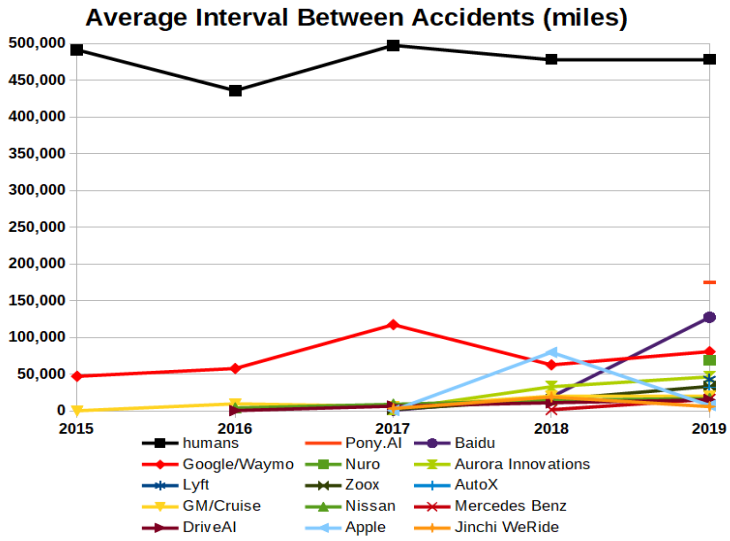
Accidents Rates/Intervals in 2019

As new arrivals to California, there is no year-over-year comparison point for Pony.AI, Nuro, and AutoX. Most other testers decreased accident rates slightly (10% to 40%). Baidu accident rates dropped in dramatic fashion: from 25x humans down to 3.75x humans. GM/Cruise accident rates rose slightly (3%).

One should not miss the relative values compared to the "humans" curves. NHTSA provides annual reports on accident rates (of human drivers) a year in arrears (most recent report is for year 2018). Human accident rates have been increasing slightly in recent years.

The least accident prone robocars (Pony.AI, Baidu, Waymo) are still 3x to 6x worse than humans. It is important to note that the Uber fatality is STILL the ONLY accident for which the AV is acknowledged at fault. NTHSA has assigned partial responsibility to Tesla on 2 fatalities, which Tesla has rejected. So "accident prone" is not equivalent to "legally liable". Insurers are likely to notice that "its never their fault" but they sure "get hit a lot".





Accident Rate (/M miles)	2015	2016	2017	2018	2019
humans	2.03	2.29	2.01	2.09	2.09
Google/Waymo	21.21	17.30	8.51	15.95	12.38
GM/Cruise	0.00	102.50	161.83	49.14	50.54
Nissan		0	0	0	0
DriveAI		0	0	0	0
Apple			0.00	12.52	0.00
Zoox			0.00	65.01	29.84
Aurora Innovations			0	0	0.00
Baidu			0	0	0
Jinchi WeRide			0.00	63.80	0.00
Mercedes Benz				0	0
Aimotive					0
AutoX					0
Lyft					0.00
Pony.AI					5.72
Nuro					0

Average Accident Interval (miles)	2015	2016	2017	2018	2019
humans	491,582	436,169	497,830	478,616	478,616
Google/Waymo	47,148	57,806	117,515	62,706	80,805
GM/Cruise	239	9,756	6,179	20,349	19,787
Nissan		4,099	9,106	14,579	16,991
DriveAI		557	6,572	11,189	15,163
Apple			838	79,845	7,544
Zoox			2,244	15,382	33,508
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** Accident rates and intervals for human drivers are taken from annual NHTSA reports. These report on "police reported accidents", so its not exactly apples-to-apples, as many of the CA AV accident reports do not result in police reports. An example report from NHTSA is available at this link.

https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812806

Accident Reports Review

California requires companies to report any accident involving a vehicle registered as AV capable. The accident report form indicates if the vehicle was operating in autonomous mode or being driven in a traditional manual fashion. We do not include in our accident reporting, accidents involving AV cars in manual mode. Occasionally, an accident report begins in autonomous mode, then includes a disengagement, and ends in manual mode. We do include these cases in our accident reporting.

Waymo, GM/Cruise, Zoox, Apple, and Pony.AI reported autonomous mode accidents in 2019. A total of 63 such accidents were reported. Overall, autonomous vehicles are extremely prone to low speed rear end collisions (63%). This no doubt is linked to them being overly cautious, detecting potential threats that humans don't see, leading to sudden stops not anticipated by the following drivers. GM/Cruise seems to be uniquely prone to corner collision accidents, from the same cause (26% of GM and 19% overall), although they have improved that metric by about 10% from last year. In the tight confines of San Francisco neighborhoods the cautious behavior tests the patience of followers, causing them to attempt passing in tight quarters. When the AV moves again before the pass, a corner collision results. This makes the over-cautious nature responsible for a total of about 82% of accidents.

	percent	total	Waymo	GM	Zoox	Pony.AI
accidents	**100%**	**63**	**18**	**42**	**2**	**1**
rear end	63%	40	14	24	2	0
corner	19%	12	0	11	0	1
bicycle	6%	4	1	3	0	0
other	11%	7	3	4	0	0
			29%	67%	3%	2%

Some difficulty in detecting bicycles (and Scooters) also still seems to be present (6%), especially from the side.

The ability to avoid accidents seems to be lacking. The programmed behavior under threat seems limited to braking. Human drivers are able to use judgment in applying acceleration and steering in addition to braking to avoid accidents.

Only Waymo, GM/Cruise, and Pony.AI experienced accidents other than low speed rear end collisions. We look in detail at a few of those accident reports in the following sections.

Waymo Accidents

	date	type	time	test miles	accident rate /M miles	normalized to humans	human rate /M miles
Google/Waymo							
2019				**1,454,491**	**12.38**	**5.92**	**2.09**
18	10/28/19	rear end	10:47:00 AM				
17	10/28/19	rear end	07:43:00 AM				
16	10/18/19	rear end	10:30:00 AM				
15	10/16/19	rear end	07:45:00 AM				
14	10/14/19	rear end	09:03:00 PM				
13	10/10/19	rear end	12:58:00 PM				
12	09/14/19	side collision	02:12:00 PM				
11	08/12/19	rear end	08:15:00 AM				
10	08/09/19	bicycle collision	09:56:00 AM				
9	08/09/19	rear end	07:45:00 AM				
8	07/08/19	side swipe	03:10:00 PM				
7	06/16/19	rear end	11:30:00 AM				
6	05/29/19	rear end	04:07:00 PM				
5	05/22/19	rear end	05:23:00 PM				
4	05/15/19	rear end	06:08:00 AM				
3	02/26/19	HS rear end	06:56:00 AM				
2	02/10/19	HWY merge	04:14:00 PM				
1	02/06/19	rear end	09:08:00 AM				

GM/Cruise Accidents

	date	type	time	test miles	accident rate /M miles	normalized to humans	human rate /M miles
GM/Cruise							
2019				**831,040**	**50.54**	**24.19**	**2.09**
42	11/09/19	rear end	09:59:00 AM				
41	11/07/19	scoot broadside	09:10:00 PM				
40	11/07/19	rear end	08:35:00 PM				
39	10/29/19	rear end	07:52:00 PM				
38	10/28/19	cut off	02:42:00 PM				
37	10/26/19	rear end	11:05:00 AM				
36	10/17/19	rear end	01:05:00 AM				
35	10/12/19	rear end	01:23:00 PM				
34	10/03/19	rear end	04:40:00 PM				
33	09/27/19	bike broadside	11:49:00 AM				
32	09/09/19	rear end	04:24:00 PM				
31	08/26/19	rear end	09:14:00 PM				
30	08/22/19	corner collision	01:13:00 PM				
29	08/07/19	rear end	10:23:00 AM				
28	08/04/19	rear end	02:32:00 PM				
27	07/20/19	rear end	08:58:00 PM				
26	07/17/19	rear end	03:02:00 PM				
25	07/15/19	cut off	11:02:00 PM				
24	07/10/19	corner collision	09:59:00 PM				
23	07/02/19	corner collision	09:47:00 AM				
22	07/01/19	corner collision	10:58:00 AM				
21	06/29/19	corner collision	11:49:00 PM				
20	06/27/19	corner collision	09:50:00 PM				
19	06/26/19	corner collision	12:36:00 AM				
18	06/23/19	rear end	12:03:00 PM				
17	06/20/19	rear end	09:03:00 PM				
16	06/13/19	rear end	04:47:00 PM				
15	06/12/19	cut off	12:47:00 PM				
14	06/08/19	rear end	09:02:00 AM				
13	05/24/19	rear end	07:36:00 PM				
12	05/18/19	rear end	07:31:00 AM				
11	05/13/19	cut off	12:32:00 AM				
10	05/08/19	side swipe	08:55:00 AM				
9	05/04/19	skateboard	10:56:00 PM				
8	05/04/19	rear end	04:39:00 PM				
7	05/02/19	rear end	11:01:00 PM				
6	04/10/19	rear end	04:52:00 PM				
5	04/10/19	side swipe	10:38:00 AM				
4	03/23/19	rear end	05:23:00 AM				
3	03/08/19	corner collision	01:29:00 AM				
2	02/27/19	rear end	06:04:00 AM				
1	01/10/19	corner collision	11:29:00 AM				

Pony.AI Accidents

	date	type	time	test miles	accident rate /M miles	normalized to humans	human rate /M miles
Pony.AI							
2019				**174,875**	**5.72**	**2.74**	**2.09**
1	06/26/19	corner pass	02:26:00 PM				

Waymo Feb 10, 2019 accident

Waymo

Human

Poor threat detection

CityTram.org

A Waymo Autonomous Vehicle (“Waymo AV”) was traveling in autonomous mode in the far right lane on southbound Highway 85 passing El Camino Real in Mountain View. A passenger vehicle entered the highway from El Camino Real and made an unsafe maneuver by crossing over a solid white line and cutting-in to the Waymo AV’s lane. Out of an abundance of caution, the Waymo AV’s test driver disengaged the autonomous mode on the Waymo AV and made an evasive maneuver into the left adjacent lane at approximately 45 MPH. As the test driver made the maneuver, the Waymo AV came into contact with a second passenger vehicle that had been approaching from behind in the left adjacent lane. The Waymo AV sustained minor damage and tire marks to the driver side of the vehicle, and the second passenger vehicle sustained no damage. The driver of the second passenger vehicle stopped to exchange information with the Waymo test driver, but after volunteering that there was no damage to their vehicle, left the scene. The first passenger vehicle did not stop.

Waymo Aug 9, 2019 accident

Waymo

Bicycle

Detection at sides

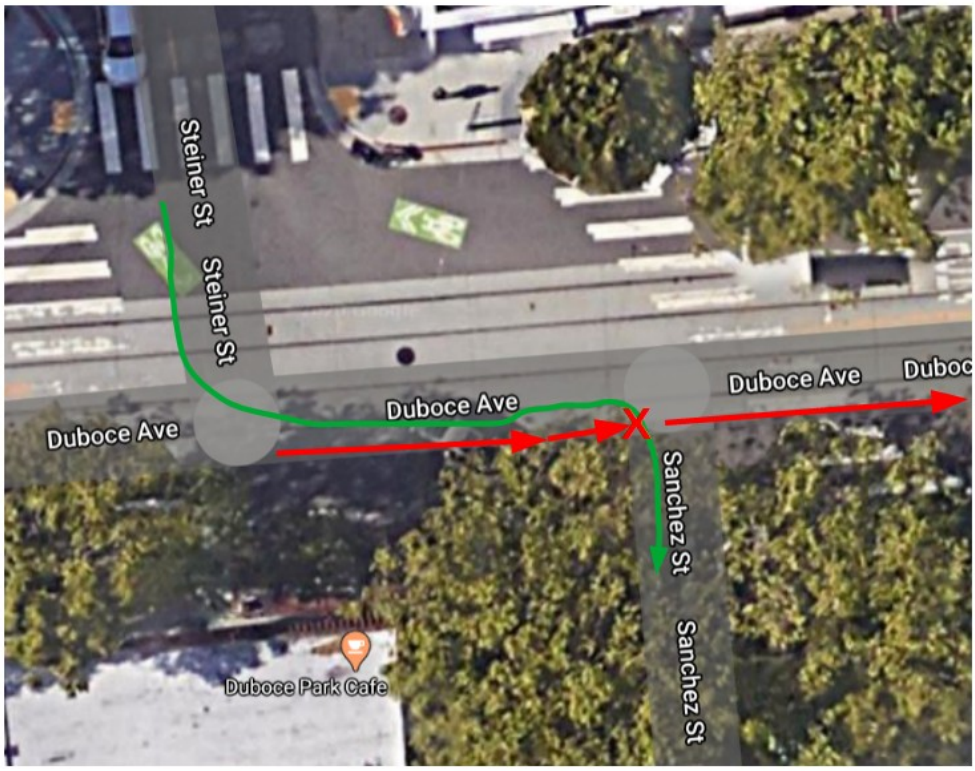
CityTram.org

A Waymo Autonomous Vehicle (“Waymo AV”) was stopped in autonomous mode on southbound N. Shoreline Boulevard at W. Middlefield Road in Mountain View when a bicyclist made contact with the side of the Waymo AV. The Waymo AV was traveling in the far right lane on N. Shoreline Boulevard and slowing for a red light at W. Middlefield Road, when a bicyclist began to cross all lanes of traffic from the east side of N. Shoreline Boulevard to the west side of the boulevard, in a diagonal manner, against the flow of traffic. As the bicyclist approached the Waymo AV, the Waymo AV began braking for the bicyclist. As the Waymo AV came to a stop, the bicyclist then made contact with the driver’s side rear quarter panel of the Waymo AV at approximately 8 MPH. The Waymo AV sustained minor scratches to the driver’s side rear taillight, and the bicyclist, remaining upright, appeared to sustain no damage or injuries as they cycled away from the scene without exchanging information.

GM/Cruise May 04, 2019 accident

RoboCar
Skateboard

Detecting
(non-car
vehicles)



A Cruise autonomous vehicle (“Cruise AV”), operating in autonomous mode, was traveling from southbound Steiner Street to southbound Sanchez Street via eastbound Duboce Avenue when a skateboarder traveling through the stop sign on eastbound Duboce made contact with the rear passenger door of the Cruise AV. The skateboarder left the scene without exchanging information. There were no injuries and police were not called.

GM/Cruise Jun 26, 2019 accident

RoboCar
Human

Slow and jerky
In turn

A Cruise autonomous vehicle (“Cruise AV”), operating in autonomous mode, was making a right turn from northbound 10th Avenue onto eastbound California Street when another vehicle made contact with the Cruise AV’s left rear bumper, damaging the upper rear fascia and lower tail light assembly. The driver of the other vehicle drove away without exchanging information. Police were not called and no injuries were reported at the scene by either party. The Cruise AV tester sitting in the driver seat did not report injuries on the scene but later mentioned injuries.

GM/Cruise Sep 27, 2019 accident

RoboCar
Bicycle

Bad at
Avoidance
(danger =
brake pedal
Is bad formula)

A Cruise autonomous vehicle (“Cruise AV”), operating in autonomous mode, was traveling eastbound on Clay Street at the intersection with Kearny Street when the Cruise AV slowed down. The driver of the Cruise AV disengaged from autonomous mode and, shortly thereafter, a bicyclist proceeding straight on northbound Kearny Street made contact with the right rear fender of the Cruise AV, damaging its fender. The bicyclist left the scene without exchanging information. There were no injuries and police were not called.

Bike attempted to cross behind vehicle. Vehicle detected threat and braked, making it harder.

GM/Cruise Nov 07, 2019 accident

RoboCar
Scooter

Bad at
Avoidance
(danger =
brake pedal
Is bad formula)

A Cruise autonomous vehicle (“Cruise AV”), operating in autonomous mode, was traveling eastbound on 24th Street at the intersection with Mission Street when the Cruise AV yielded to an electric scooterist traveling northbound on Mission Street and violating a red light. The driver of the Cruise AV disengaged from autonomous mode and, shortly thereafter, the electric scooterist made contact with the right rear corner of the Cruise AV, damaging the Cruise AV’s right rear fascia and brake light. The electric scooterist left the scene without exchanging information. There were no injuries and police were not called.

Scooter attempted to cross behind vehicle. Vehicle detected threat and braked, making it harder.

Pony.AI Jun 26, 2019 accident

A Pony.AI autonomous vehicle ("Pony AV") in autonomous mode was traveling southbound on Pine Street heading towards Cameron Hills Drive. A passenger vehicle traveling southbound behind the Pony AV crossed the traffic line and entered the northbound lane of Pine Street in an attempt to pass the Pony AV. The Pony AV's speed remained consistent. After passing the Pony AV by about a quarter car length, the passenger vehicle abruptly turned back into the southbound lane of Pine Street such that it was in very close proximity to the front of the Pony AV. The passenger vehicle then suddenly decelerated. The Pony AV's safety driver disengaged autonomous mode and manually applied the brake. As a result of the passenger vehicle's sudden deceleration, the Pony AV's front-left bumper made contact with the back-right bumper of the passenger vehicle causing minor scratches to both vehicles. The safety driver of the Pony AV and the driver of the passenger vehicle stopped to exchange information. No injuries were reported and the police were not called.

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CityTram is about improving the way Americans commute in and around our cities. That is not, in and of itself, the end goal. It is simply the most practical and achievable means by which the end goal might be achieved. The end goal is to fight back against climate change. Since governments have proven to be wholly incapable of fighting climate change, it is left to we individuals to try. Using the powerful leverage of commercial interest to effect social change seems the smartest approach. This is the framework into which the CityTram project fits.

We make no effort to convince anyone that climate change is real, nor man-made, nor fixable, nor fixable at an affordable price. But we believe all of those, and it provides our motivation for this effort.