Patent Filings & Innovation Trends – Autonomous Vehicles

2010 – 2017

BooleanIP
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Executive Summary

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Autonomous Vehicles' domain has seen patenting activity mostly in the last 7 years and most promising patents have been filed in last 7 years only. Accordingly, this study was restricted to patents filed after 2010. Looking at high number of filings happening in this domain by enterprises of all sizes, universities and researchers etc., it becomes much vital to have a keen evaluation of the patenting activity to understand the innovation trends.

The initial research aims to give the readers a clear insight regarding the comparative patenting activity among different players in the domain. A closer look at the patenting activity demonstrates a constant rise in the filing specifically after 2011 wherein a steep rise globally can be observed.

This motivated us to take a deeper dive and analyze critically the various parameters and control systems of Autonomous Vehicles. Further, country-wise (DE, JP, KR, US, CN etc.) patent filing trends in autonomous vehicles were also evaluated while also revealing the major players in each category. A comparative analysis of R&D strategy and portfolio strength for few major players was also evaluated.

Finally, a few prominent recommendations were identified for the players in Autonomous Vehicles that shall help them evaluate the scope of their innovation & opportunities of expansion.

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1. INTRODUCTION

Self-driving cars are finally here, and how they are deployed will change how we get around forever. From Tesla to Google to Uber to all the major automakers, we bring you complete coverage of the race to develop fully autonomous vehicles. This includes helpful explanations about the technology that underpin the movement to build driverless cars. While the technological feasibility of autonomous vehicles is being demonstrated by Google, Audi, Volvo, Bosch, and Continental, important obstacles such as high costs and the lack of a legislative framework remain in place. On the other hand, the multiple benefits of autonomous vehicles in terms of safety, cost savings, and efficiency, as well as positive impact on the economy and society as a whole, are driving research and development efforts globally. With ADAS-type features already being implemented on a wide scale, the next step for autonomous vehicles will materialize in the next decade. Fully autonomous, self-driving, robotic vehicles will start appearing between 5 and 10 years from now. The disruptive effects of autonomous driving are only just being discovered and its transformative impact on the auto industry and society as a whole will be huge with car sharing and declining vehicle ownership being two of the main exponents. This study discusses some of the recent patent and technology trends in autonomous vehicles. However, before we start analyzing or evaluating the trends and activities in this domain, it is imperative to understand the various terminologies, evaluation parameters for patenting activity, etc. used in this study:

1.1. Evaluation Parameters for Studying Patenting Activities

Patent activity herein is a measure of innovation and globalization in terms of patent applications for the period 2010 onwards. Patent applications are counted in terms of first filings and foreign filings. First filings are an indicator of innovation and inventive activity, while foreign filings are an indicator of an intention for international trade and of globalization.

Further, all the data presented here is restricted till 2016 as patent applications having their first filing data in 2017-2018 might not be published yet (there is an 18 months lag between filing and publication of patent applications).

1.2. Relevance Criteria for Screening and Shortlisting documents

As a first step, all those documents were screened that discussed control systems and various parameters in autonomous vehicles. The screened documents were then semi-automatedly analyzed to shortlist documents that disclosed:

1. Drive control systems purposes;
2. Driving parameters;
3. Control system details

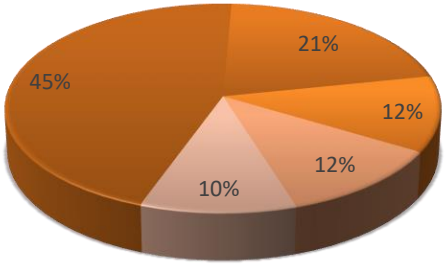
The shortlisted documents were further analyzed in details to identify more relevant information.

2. OVERALL TECHNOLOGY ANALYSIS AND TRENDS

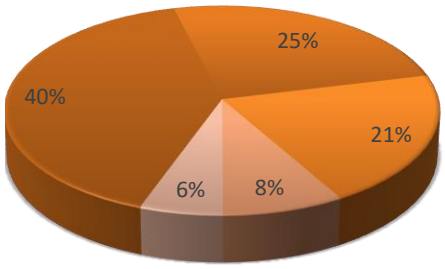
Below table shows the patents categorized in different technology areas in the domain of autonomous vehicles.

Autonomous Vehicles	Drive Control Systems Purposes	Vehicle driving stability
		Automatic manoeuvring for parking
		Path keeping
		Adaptive cruise control
		Propelling the vehicle
	Driving Parameters	Ambient condition Parameter i.e. traffic, road conditions
		Drivers Related Parameter
		Vehicle motion Parameters
		Parameters related to vehicle itself
		Obstacle detection
	Control System Details	Control System details
		Adapting control system settings
		Ensuring safety in case of control system failures

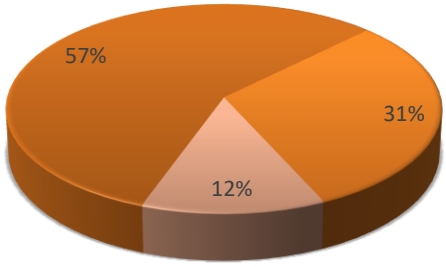
Drive Control Systems Purposes



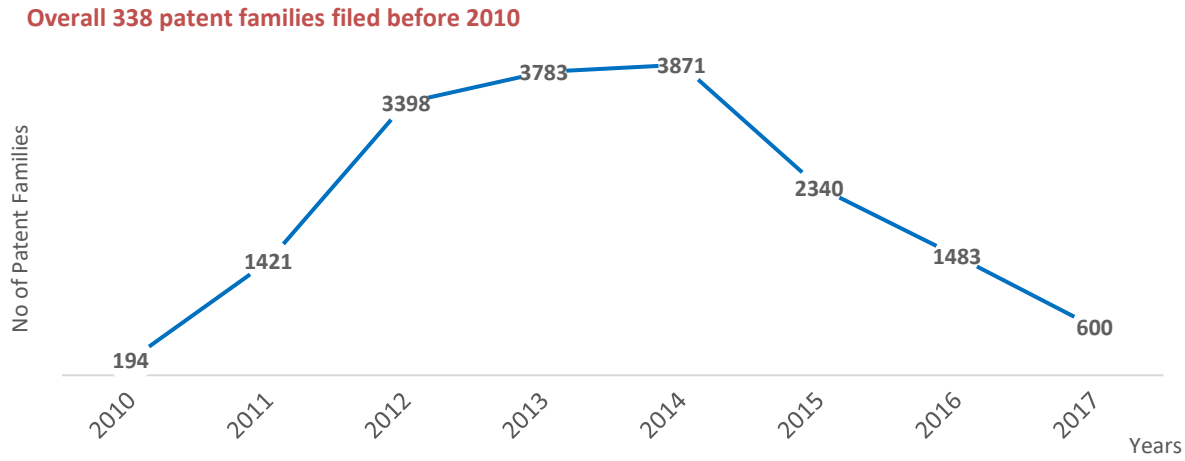
Driving Parameters



Control System Details



It's surprising and interesting that patents related to obstacle detection are lesser than other categories in driving parameter technology domains.

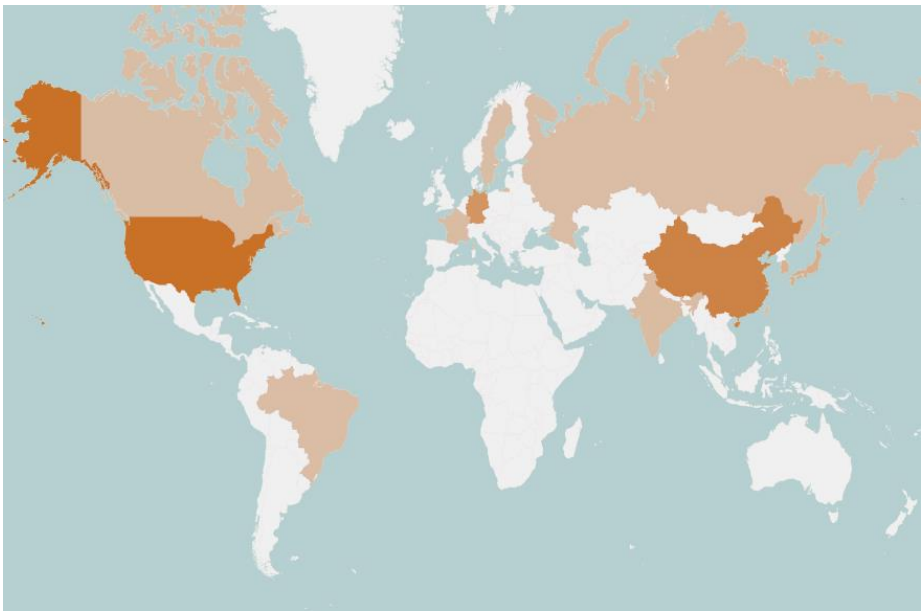


Above chart shows the patent filing trend of autonomous vehicles. There appears a consistent rise after 2011 which suggests a possibility of commercialization of the technology during that period. It must be noted that patent filing data is not complete for 2016 and 2017 since most of the patent applications filed in these years wouldn't have been published till date.

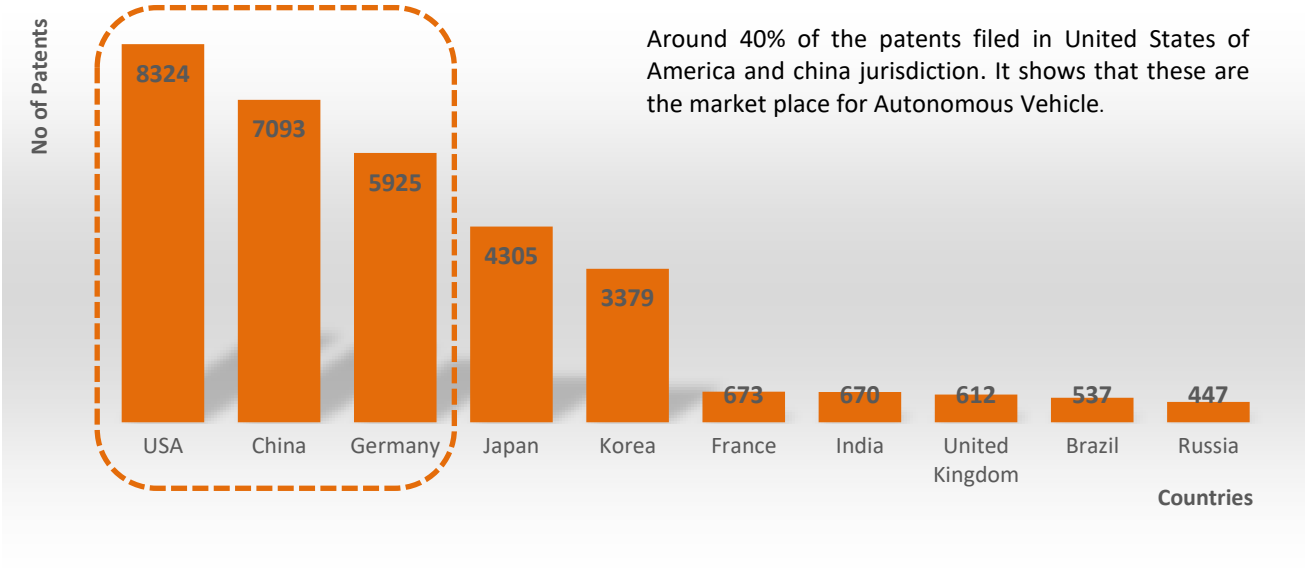
3. OVERALL GEOGRAPHICAL COVERAGE OF PATENTING ACTIVITIES

3.1. Share of favourable markets in Patenting Activities

The chart below shows the number of patent families published in different jurisdictions. The technology is being protected in these countries which may denote that the innovators are seeking these geographies as most favorable market for their invention.



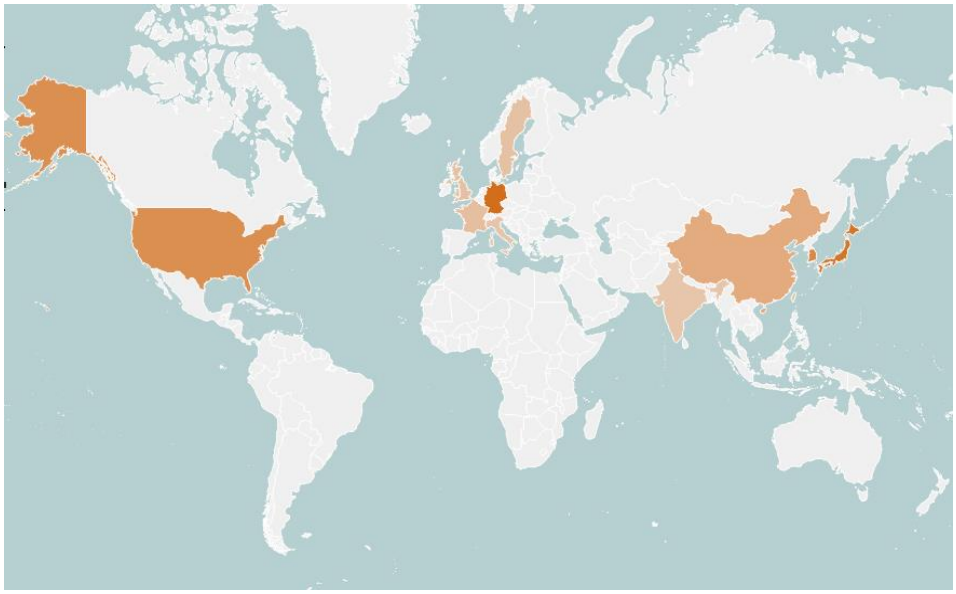
Maximum of the patents (around 60% of total filings) have been filed in **China, USA and Germany**. It shows that these are the market place for Autonomous Vehicles.



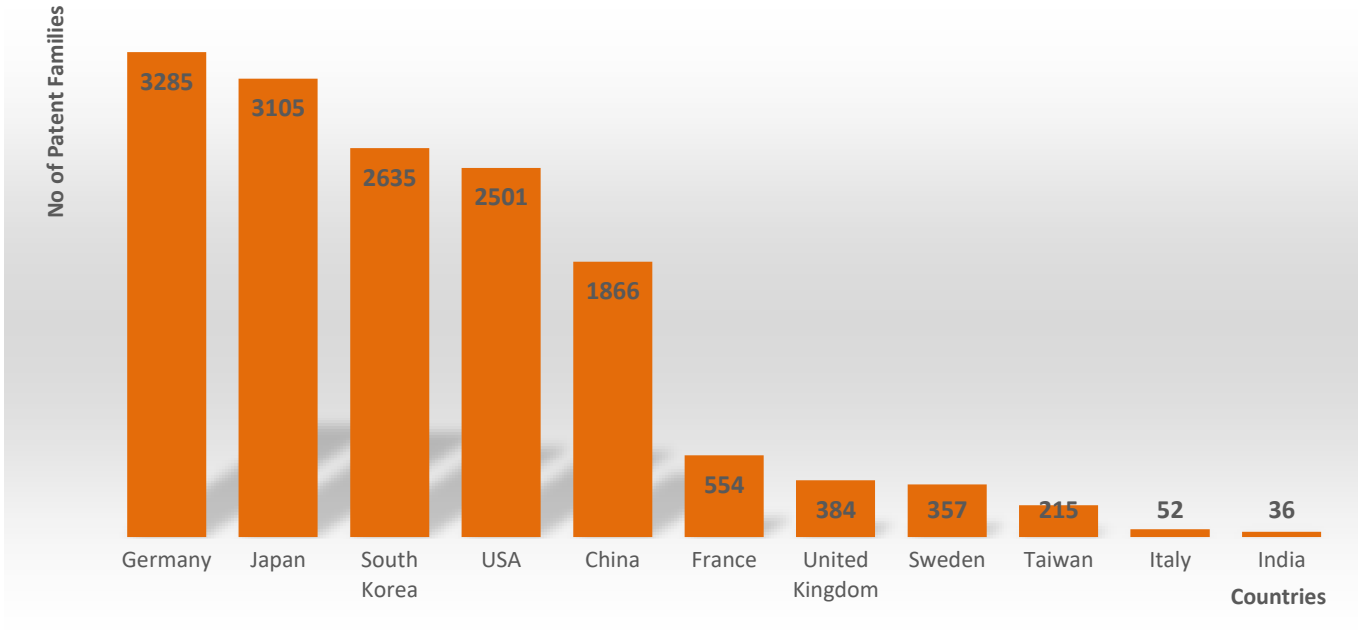
Around 40% of the patents filed in United States of America and china jurisdiction. It shows that these are the market place for Autonomous Vehicle.

3.2. Share of active innovation countries in Patenting Activities

The chart below shows the number of patent families first filed in different jurisdictions. The technology is being first protected in these countries which may denote that the innovations are originating in these countries.



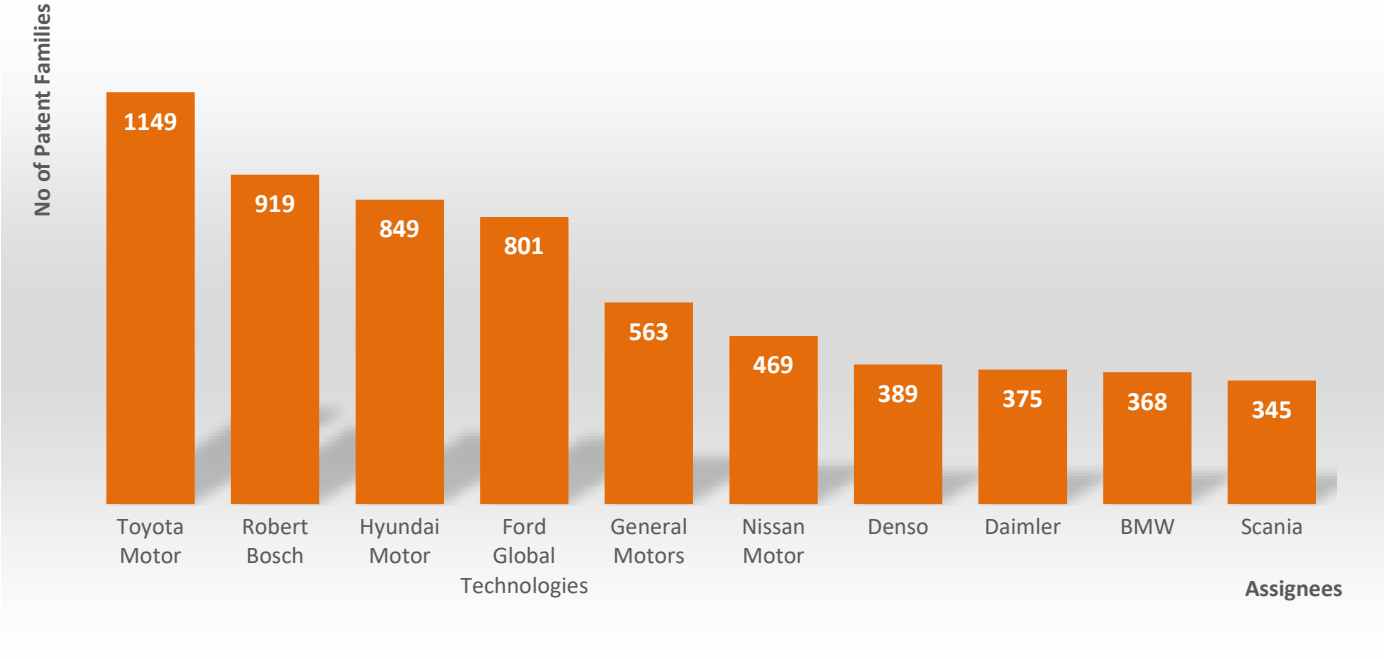
Around **40%** of the patents filed in **Germany and Japan** have been filed from 2011. It means Germany and Japan are the innovation hub



4. ACTIVE PLAYERS AND INNOVATORS

4.1. Active patent assignees in this area

The chart shows the major players in the technology domain related to Autonomous Vehicles.

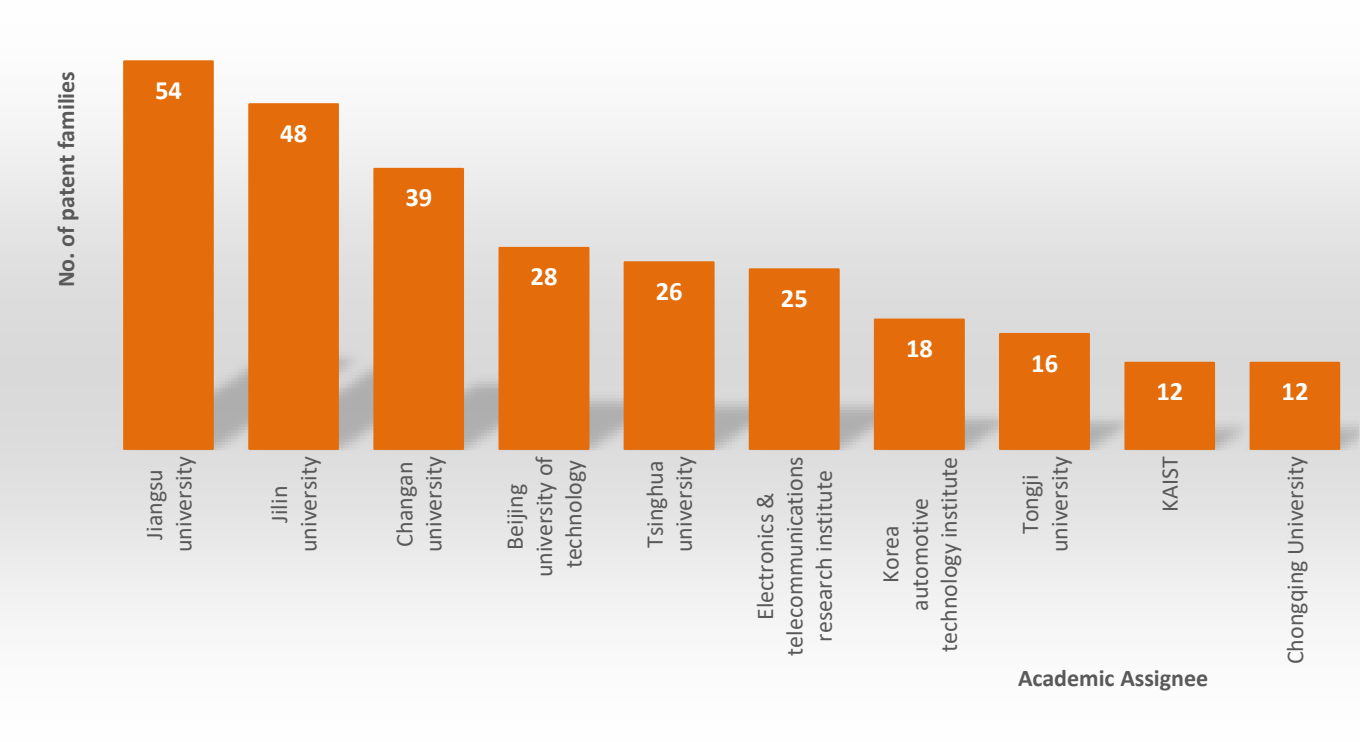


Most of the patents are filed by OEMs and suppliers. Since the technology is costly and require governmental regulations and permissions mostly big players only are currently working in this domain. Although Google has been working in this domain for long but their patents are not directly related to vehicles. This could be a reason patents from Google are not highlighted here.

4.2. Universities and Academic Assignees

The table below shows the major academic assignees in the technology domain related to Autonomous Vehicles

Top Academic	Country	Top Inventors
Jiangsu university	China	Jiang Haobin (27) | Ma Shidian (22) | Hua Yiding (14)
Jilin university	China	Guo Hongyan (7) | Hao Ningfeng (7) | Chen hong(6)
Changan university	China	Wang Chang (13) | Fu Rui (10)
Beijing university of technology	China	Xi Junqiang (3) | Bi Luzheng (3) | Chen Huiyan (3)
Tsinghua university	China	Li Keqiang (14) | Wang Jianqiang (12)
Electronics & telecommunications research institute	Korea	Sung Kyung-bok(3) | Han Woo-yong(3)
Korea Automotive Technology Institute	Korea	Bae Chul Yong (5) | Lee Bong Hyun (5)
Tongji University	China	Zhang Lijun (3) | Zhang Pinjie (2)
Korea advanced institute of science & technology (KAIST)	South Korea	Suh In Soo (5) | Kim Jun Mo (3)
Chongqing University	China	Lu Junfu (2) | Shi Shaohui(2) | Lu Sheng (2)



4.3. Active Inventors in this area

The table below shows the major inventors in the technology related to Autonomous Vehicles.

Inventors (with corresponding assignees)	Number of Patents Families
Nordbruch Stefan (Robert Bosch)	83
Kuang Ming Lang (Ford Global Technologies)	69
Yamazaki Mark Steven (Ford Global Technologies)	63
Doering jeffrey allen (Ford Global Technologies)	63
Wang Xiaoyong (Ford Global Technologies)	56
Nedorezov Felix (Ford Global Technologies)	55
Nefcy Bernard D (Ford Global Technologies)	53
Mielenz Holger (Robert Bosch)	52
Liang Wei (Ford Global Technologies)	52
Johri Rajit (Ford Global Technologies)	50

Maximum of Inventors are from Ford and Robert Bosch and they are focusing on Drive Control Systems Purposes.

5. KEY ASSIGNEES ACTIVITIES IN AUTONOMOUS VEHICLES

5.1. Key Assignees and their activities in technical sub-categories of Autonomous Vehicles

Assignees v/s Technology Share	Drive Control Systems Purposes	Driving Parameters	Control System Details
Toyota Motor	40%	38%	6%
Robert Bosch	43%	27%	13%
Hyundai Motor	36%	37%	13%
Ford	46%	20%	10%
General Motors	47%	23%	11%

Major Players seems to be a prolific filer in the domain of Purposes of road vehicle drive control systems specifically on Propelling the vehicle.

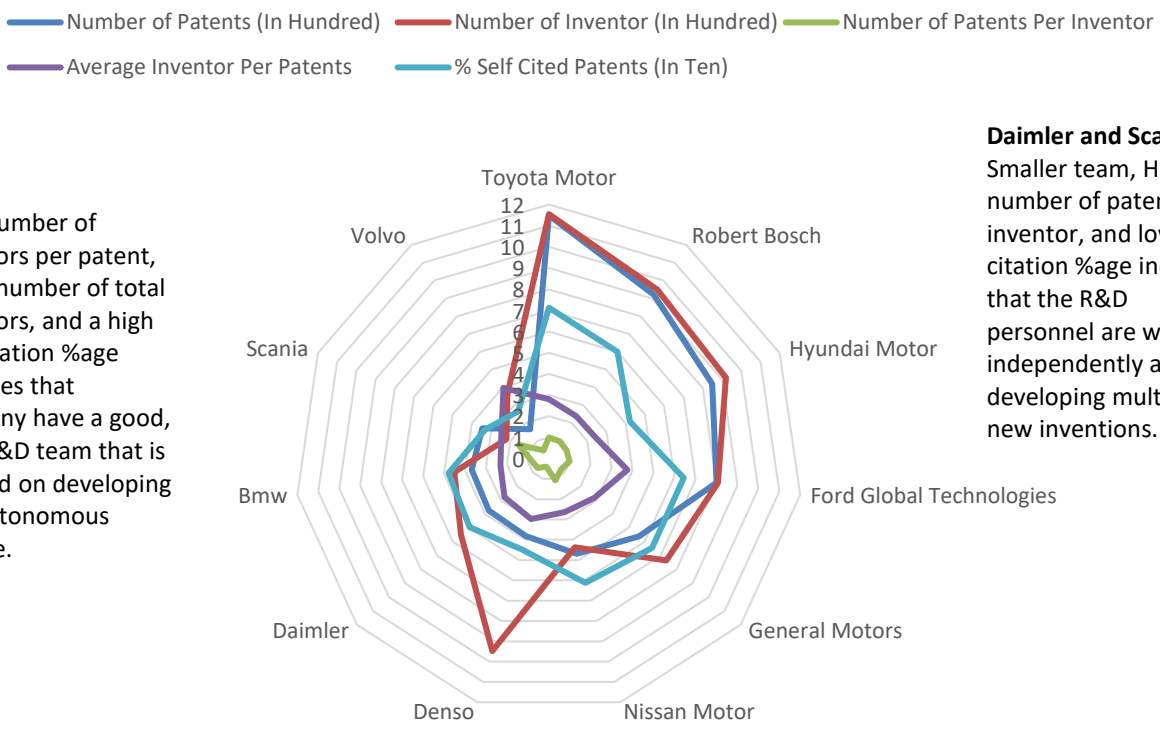
5.2. Key Assignees and their filing activities in Autonomous Vehicles' domain.

Assignees v/s Market Geographies	JP	US	CN	EP	KR	IN	CA	RU	DE	FR	MX
Toyota Motor	1051	871	645	301	114	92	0	2	318	0	0
Robert Bosch	110	291	328	240	63	51	0	0	875	95	0
Hyundai Motor	121	517	401	14	830	0	0	0	245	0	0
Ford	0	990	732	13	0	16	0	15	776	0	71
General Motors	0	535	484	0	11	8	0	0	548	0	0

Germany and USA seem to have a lot of market opportunities

COUNTRY CODES					
JP	JAPAN	US	USA	CN	CHINA
EP	EUROPE	KR	SOUTH KOREA	IN	INDIA
CA	CANADA	RU	RUSSIA	DE	GERMANY
FR	FRANCE	MX	MEXICO		

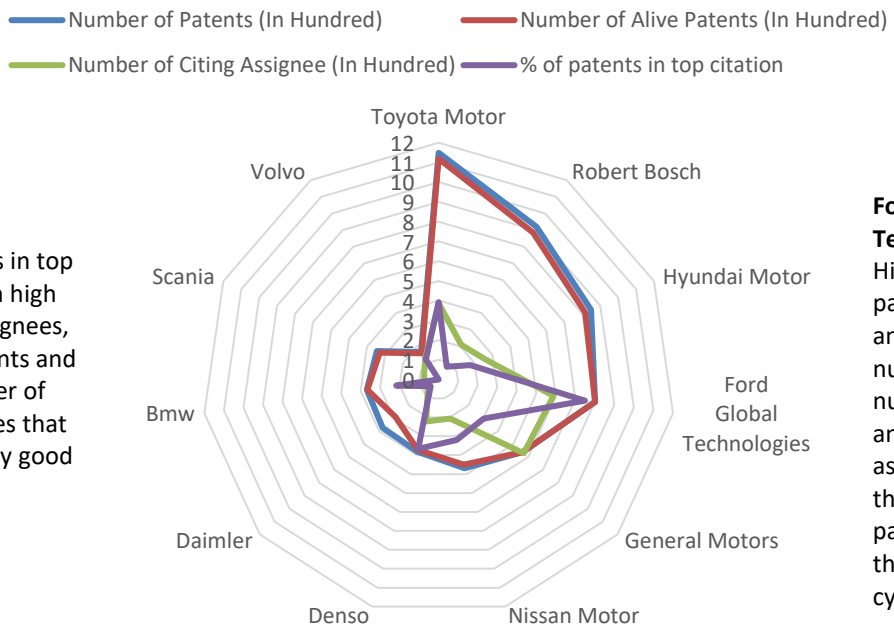
5.3. Key Assignees Comparative Analysis for R&D strategies.



Volvo
High number of inventors per patent, lower number of total inventors, and a high self-citation %age indicates that company have a good, core R&D team that is focused on developing the Autonomous Vehicle.

Daimler and Scania
Smaller team, High number of patents per inventor, and low self-citation %age indicates that the R&D personnel are working independently and developing multiple new inventions.

5.4. Key Assignees Comparative Analysis for Portfolio Strength



Toyota Motor
High %age of patents in top citation coupled with high number of citing assignees, high number of patents and the maximum number of alive patents indicates that the company has very good patent portfolio.

Ford Global Technologies
High number of %age of patents in top citation and almost equal number of patents, number of alive patents and the number of citing assignees indicates that the company holds good patent and maintains them through out life cycle of patents.

6. INSIGHTS & RECOMMENDATIONS

Nearly 37,000 Americans die each year in car accidents, and nearly 1.3 million die globally. For every death in the U.S., there are more than 100 treated in emergency rooms, with an annual cost of $33 billion in 2012. Self-driving here means a reduction in health-care costs; it also means that the car insurance industry changes completely, and that traffic congestion due to accidents severely drops.

The significance of the intellectual property of autonomous vehicles' inventions is quite evident from the innovation trends witnessed across all sub-categories of domain in major countries and globally. This can also be made from the fact that autonomous vehicles are already a common sight on the streets of Silicon Valley, an international hub for self-driving technology. Also, California set the stage for the next phase of innovation that could dramatically alter transportation and mobility across the globe. The state has proposed regulations to allow fully autonomous vehicles to drive on public roads – meaning empty cars with no steering wheels and no backup driver inside.

Apart from that California recently overtook the UK to become the fifth largest economy in the world, and there are a total of 27 companies that now have permits to test autonomous cars on the road, though current rules require a human behind the wheel. With a total of 180 vehicles approved for operation, there are already six times as many vehicles permitted on public streets here compared with 2014 – and probably more than the rest of the US combined.

Waymo is Google's recently renamed self-driving car operation. Seated in the passenger seat of a Waymo on a sunny afternoon in Mountain View, Jaime Waydo, head of systems engineering, recited a string of alarming statistics – 1.2 million people die on the road each year, equivalent to a 737-plane falling out of the sky every hour. In 94% of the cases, the cause is human error.

Autonomous vehicle technology is an emerging global market. By 2025, the car market for partially autonomous vehicles is expected to be at 36 billion U.S. dollars while the market for fully autonomous vehicles lags behind at 6 billion U.S. dollars.

Examples of autonomous vehicle technology components include driver assistance systems, automotive radars, ADAS ultrasonic wave components, LiDAR system sensors, among many others. The global market for automotive radars stood at 1.2 billion U.S. dollars in 2015 and is projected to grow significantly by 2022.

Moreover, consumer interest for autonomous vehicles is growing around the globe. In 2016, a poll by the MIT in the U.S. found that 19 percent of respondents aged between 35 and 44 were willing to use partially autonomous vehicles, while 15.4 percent of respondents aged 75 or older said the same.

Self-driving cars are a rapidly evolving technology which only a few years ago was still considered science fiction. In such a dynamic context, quick intuitions can be very misleading and misconceptions about the technology, its impact, and the nature of the innovation process abound. Despite all the evolution in this domain people may find it difficult to fully rely on autonomous vehicles because of certain misconceptions about autonomous vehicles. Some of the widely held misconceptions about autonomous vehicles are mentioned below:

- Driver assistance systems will evolve gradually into fully autonomous cars
- The first models of fully autonomous cars will be targeted to the consumer and will be available for purchase
- It will take decades until most of the vehicles on the road are capable of autonomous driving
- Self-driving cars are controlled by classical computer algorithms (if-then rules)
- Public demonstrations of self-driving cars provide an indication of their capabilities
- Self-driving cars need to make the right ethical judgements
- To convince us that they are safe, self-driving cars must drive hundreds of millions of miles
- Self-driving cars will increase congestion in cities

It's hard to say when in the next few years we will find the technology solid enough to remove safety drivers. But when we do, expect the speed of growth to be potentially faster than typical technology-adoption curves, which were already accelerating. Without a massive upfront cost being borne by consumers, there is a potential for growth metrics that feel closer to Uber and Snapchat than the growth of cars and air travel. If GM, Toyota, Uber or another company decides to ship enough cars to bring a city like Los Angeles online, then you could see the kind of disruption in urban mobility that we haven't seen in 100 years in a matter of months.

7. REFERENCES

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- Lens.org – A freely available Patent Search Database

Websites

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- news.mit.edu
- spectrum.ieee.org
- www.statista.com

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- A Paper on, "Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations", published July 2015 - By Daniel J.Fagnant et al.
- "Autonomous Cars Self-Driving the New Auto Industry Paradigm" – By Morgan Stanley Research.
- "Autonomous vehicles' disengagements: Trends, triggers, and regulatory limitations" – By FrancescaFavarò et al.