Questel

Autonomous Driving and Smart Transportation

2022 Patent landscape

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Executive Summary

An autonomous driving vehicle can operate on its own and perform the required tasks without human intervention due to its ability to sense its environment. The vehicle primarily employs artificial intelligence (AI), and multiple detection and ranging systems and navigate by forming an active 3D map of that environment. Automation of routine tasks is currently a concept that is gaining a lot of interest from several industries. With the rapid adoption of the Internet of Things (IoT), and the implementation of 5G, the global transportation infrastructure is changing rapidly. Furthermore, the rise of smart cities is bringing to life an ultra-connected infrastructure providing an ideal catalyst for autonomous vehicles. Driverless cars, trucks and buses can be intrinsically connected to vital information that reduces traffic and makes driving on the roads safer. Autonomous vehicles can interact with smart traffic lights to enable congestion-free traffic flow. Autonomous driving and smart transportation have been widely reported in recent times. Numerous market forecast surveys and patent landscapes on this topic have emerged (WIPO, EPO, McKinsey & Co, KPMG, etc.). Most of these various studies reveal a considerable growth in terms of number and size of patents and a promising assessment of the market value.

The current report has covered a global patent landscape study focused specifically on autonomous driving and smart transportation, analyzing the various trends between 2010 and 2022. This study has been divided into two main topics, Autonomous Driving and Smart Transportation. For each topic, it defines filing trends, R&D origins, market countries, key players, as well as technology segments. In addition, it uses reference information from various sources to enrich the analysis, allowing for revealing business and technological insights.

AUTONOMOUS DRIVING

A total of 49,000 patent families have been filed on Autonomous Driving-related technologies worldwide since 2010. A significant boost has been seen recently with over 75% of these applications filed since 2016, and a Compound Annual Growth Rate (CAGR) of 24% between 2010 and 2020.

The landscape shows also strong variations in the level of R&D efforts in this field between the various countries and companies.

Overall, there is a Chinese leadership in terms of patenting activity. One half of these inventions come from China, whereas only 17% of them come from the United States. Japan contributes close to 11% of total filings, followed by Germany and South Korea with 8.3% and 8%, respectively. More specifically, growth rates between 2010 and 2020 reveal a strong filing activity in Asia, with a CAGR of 32% for China, nearly 17% for Japan and 15.5% for South Korea. The

United States shows a growth rate of 28.5% for the same period which puts it well behind China. However, a smaller ratio of granted patent families to total patent applications rate in China could mean slightly fewer high-quality inventions from China than from the United States.

In terms of geographical market, China offers a large market for autonomous driving. 64% of the patent publications were published in China, which shows its position as the leading market. This status is further strengthened by the intensity of patent filings from China. The United States comes at 28%, followed by 15% in Japan, and 12% in Germany. Nevertheless, most Chinese patent applications are published exclusively in China, and only 1.8% of Chinese applications are extended to the United States, which is the main Western market of interest for Chinese patents.

In terms of players, a significant presence of Chinese players is clearly noticed in the patenting activity of Autonomous Driving related technologies, accounting for 7.2% of global patents. The competition is tight in the top players between Chinese, Japanese, German, and American companies, which are mainly car manufacturers, companies specializing in autonomous driving, automotive suppliers and other software, telecommunications, and information technologies. The top patent filing players are led by the Chinese Internet giant Baidu, followed by the Japanese automobile manufacturer, Toyota, and Robert Bosch.

The level of aggressiveness in this field is currently low, most likely driven by the lack of maturity of the technologies. More litigation may arise in the coming years, and it will be interesting to observe to what extent the differences in leverage brought about by the respective sizes of the companies' patent portfolios may impact their future market positions.

SMART TRANSPORTATION

Concerning Smart Transportation, 35 858 patent families have been detected since 2010. The CAGR value recorded between 2014 and 2020 was 28%, a value that displays a strong position for Smart Transportation among other new generation technologies. Moreover, the landscape reveals considerable diversity in R&D levels across countries and companies.

Similar to its position for autonomous driving, China shows a strong dominance in this area as well, with 46% of global patent filings related to Smart Transportation technologies. The United States comes in second with 19%, followed by 14% for Japan, 8% for Germany and just 6% for South Korea. More importantly, China's growth rate remains steady at a CAGR of 31% from 2010 to 2020. The United States follows China with almost the same pace, with a CAGR of 30% for the same period. Meanwhile, it is worth taking into consideration the fact that South Korea has achieved a very significant CAGR of 39% from 2015 to 2020. On the other hand, the ratio of granted patent families to total patent

applications is weaker in China than in the U.S.; from 2010 to 2018, 42% of Chinese patent applications are granted while the rate is 78% for U.S. applications. This trend could be explained by the number of revoked and abandoned Chinese patents coming mainly from academic players.

In terms of geographical market, 38% of patent families have been published in China, a number that demonstrates the importance of China as a major market. USA and Japan follow with 17% and 10% respectively. However, most Chinese players are not focused on the foreign market, as most Chinese inventions are only protected in China and only about 3.5 % of Chinese applications are extended to the United States, making it the main Western market for Chinese patents.

In terms of players, the list of top 50 shows a clear domination of companies specialized in automotive or related activities. Other players from the electronics, semiconductor, Internet, and telecommunications industries are also present. In addition, interest in the field is spread across different geographical areas with 16 Chinese (including 10 academics), 11 American (all industrial), 9 Japanese, 6 German and 4 South Korean players among the top 50. The leading patent applicant in the Smart Transportation field is the Japanese automaker Toyota with 3.6% of the global patents followed by the Chinese Internet company Baidu, with 2.8% share of inventions. The Japanese automotive manufacturer Honda came third with 1,8% and the German automobile supplier Robert Bosch ranks fourth on the list with 1,7% of the total number of patents.

As of today, the level of aggression in this field is incredibly low compared to the total number of patent families and the number of infringements in other technical domains. This number may be predisposed to increase when intelligent transportation is widely deployed. Litigation could be even more numerous as inventions are not just coming from traditional automotive manufacturers and suppliers, but also involve various technical fields such as computing and telecommunications.

Introduction

Autonomous Driving

History of self-driving technology

The earliest self-driving technology dates to 1925, when Houdina Radio Control, a Radio equipment company, designed a Radio self-driving car. According to the New York Times at that time, "The driverless car will travel about the city through the heaviest traffic, stopping and starting, turning, sounding its horn and proceeding just as though there was an invisible driver at the wheel."

In the early 1990s, Dean Pomerleau, a researcher at Carnegie Mellon University, proposed using neural networks to allow self-driving cars to acquire raw images from roads in real time for directional control. He argued that the approach using neural networks is more effective than other attempts to manually classify images into "road" and "non-road" categories.

After 2015, with the rise of artificial intelligence technology, many companies began to focus on self-driving cars: In 2016, BMW and Intel announced a self-driving project, and General Motors acquired self-driving startup Cruise; In 2017, Mercedes-Benz and Bosch announced the joint development of SAE Level 4 and above autonomous driving technology. Since then, autonomous cars have entered the public's vision and won more and more attention.

Five levels for autonomous vehicles

The Society of Automotive Engineers (SAE) International has defined six levels of automation – from no automation (Level 0) to full automation (Level 5)

- **Level 0**: No Automation
  This is the traditional level of driving where the full control is performed in all aspects at all time

- **Level 1**: Driver assistance
  Cars can't control steering and speed at the same time, so drivers need to assist with control and monitor road conditions and take over when the car can't drive itself.

- **Level 2**: Partial automation

The vehicle can steer, accelerate, and brake automatically. Drivers need to interact with the external environment, such as observing traffic lights, observing the surrounding environment, changing lanes and so on.

- **Level 3**: Conditional automation
  The vehicle can drive and monitor the environment, but the driver still needs to intervene in situations where navigation is impossible.

- **Level 4**: Highly automated
  There is usually no need for human intervention and supervision. In extremely harsh or unusual environments, a take-over request is issued to the driver. If the driver does not respond, the system can automatically switch to the minimum risk state.

- **Level 5**: Fully automated
  The vehicle no longer has a steering wheel and pedals, so it can do all the driving activities without the driver taking over.

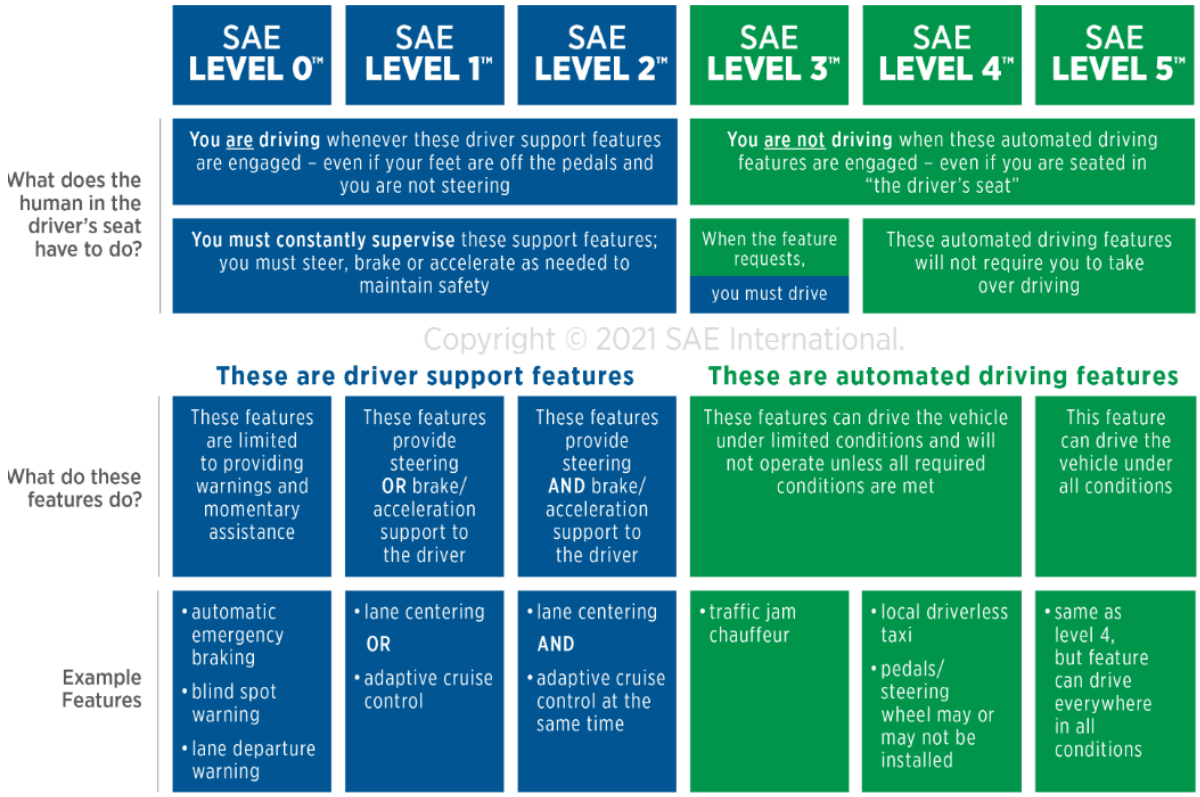


Figure 1 – SAE levels of Driving Automation

Smart transportation

An intelligent transportation system includes not only the smart vehicles, but also intelligent public infrastructure comprising interaction with road equipment,

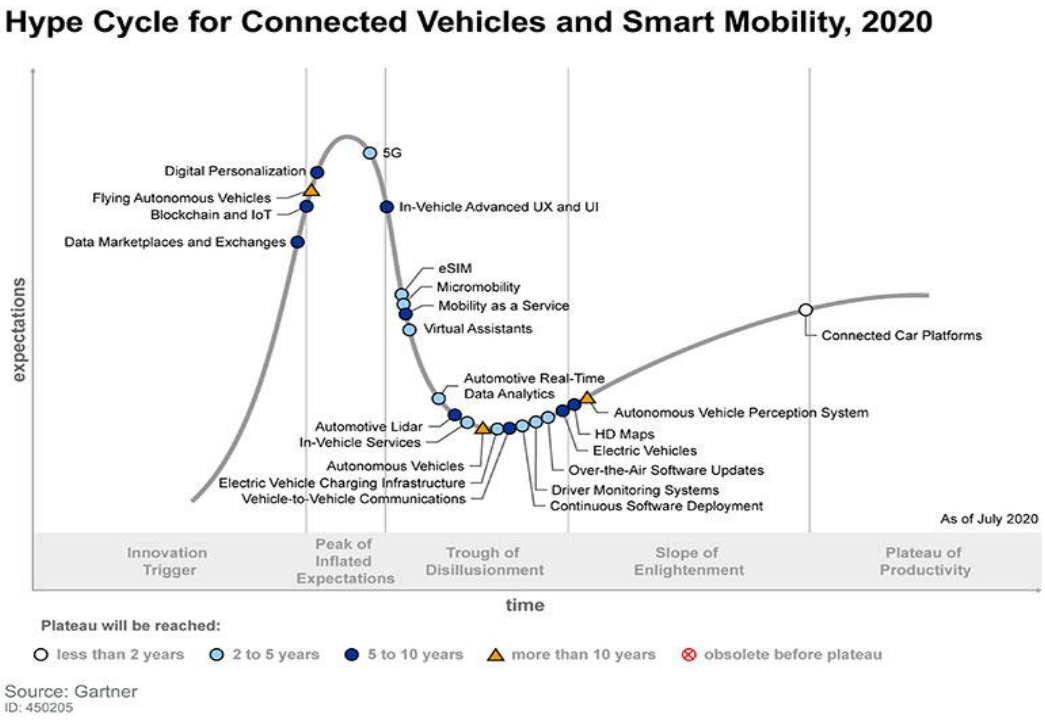
traffic lights, and processing and analytical services from network-based modules or devices. Smart transportation benefits from the proliferation of the Internet of things and 5G services. It takes advantage of those technologies to connect, coordinate and adjust exchange between vehicles, and vehicles and infrastructure making a better use of resources in the city while reducing accidents.

It is a technological field arousing investments interest. The growth is driven by increasing innovative city projects and government programs around the world. Smart transportation systems simplify and enhance traffic management safety and facilitate the use of intelligence in modern transportation networks.

Autonomous driving and smart transportation landscape: A need

The success of autonomous vehicles includes the development of various technologies, such as automatic emergency braking, the Internet of things, 5G, automotive lidar, V2V, software development, HD maps, image recognition, traffic information recognition, as well as the support of the network.

Since the development of these technologies requires the protection of patents, the number of relevant patents can reflect the development of the industry and the degree of attention.



Source: Gartner
ID: 450205

Figure 2 – Hype cycle for connected vehicles and smart mobility, 2020

According to the 2020 hype cycle[1], the IoT and 5G technology closely associated with smart transportation are at the peak of expectations, indicating that the technology is in the rising stage and companies will face fierce competition. Some companies will be eliminated from the market. Technologies related to self-driving cars, such as lidar, electric vehicles, V2V, and software, are at the trough of disillusionment phase. Due to the lack of competitiveness, many companies are already out of the market, while the rest need to overcome the problems and adjust their strategy to enter the slope of enlightenment stage.

It is necessary for companies involved in these technologies to align their IP strategy to protect their products and designs. Therefore, studying the patent landscape is a need to better understand the development status and future trends of autonomous driving and smart transportation.

[1] https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/documents/Gartner-connected-vehicles

Methodology

Patents search strategies

Data source

The data source used in this study is FamPat worldwide database search tool Orbit Intelligence. FamPat is a global collection of patent applications and granted patents organized by simple patent families, covering more than 100 patent authorities all over the world, including searchable full text from 63 patent offices, provided by Questel.
As each Fampat record contains potentially many individual publication events all with different dates, the report uses the earliest known office of first filing date for each patent family. This is considered as the representative patent family member which is being used to refer to the patent family. The office of first filing (OFF) or priority, refers to the first application for a particular invention which, when filed at any patent office becomes the “priority application”, with the date of this event defining the priority date. The country of the first filing is defined as the first priority country.

The tables and charts included in the report use this priority date, unless otherwise noted, because it provides the most accurate indication of the inventive activity. The definition of patent sources, i.e., the location from which patent families are emanating, is based on the Office of First Filing (OFF). It should be noted that this definition is not 100% accurate, nevertheless, it provides a useful and fair method of identifying the usual country of first filling of entities, which typically coincides with their home patent office.

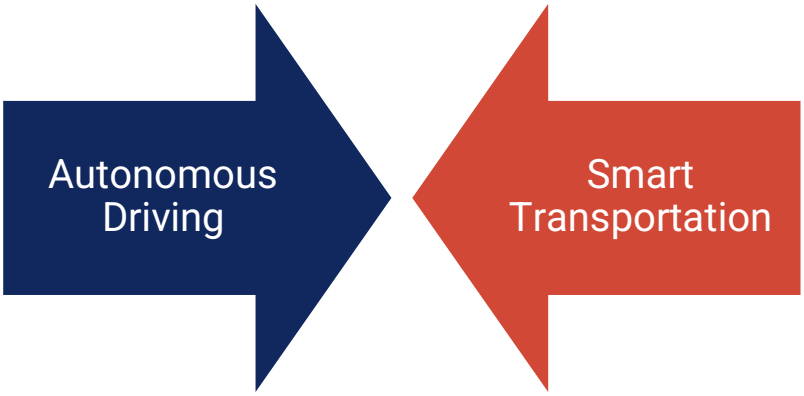
As mentioned previously, the current study focuses on Autonomous Driving and Smart Transportation technologies, major elements in the new technological revolution.

The search was performed by employing several strategies, using Autonomous driving, Smart Transportation, and their associated techniques keywords as well as relevant patent classifications (such as B60W60/00: drive control systems specially adapted for autonomous road vehicles). The relevance of the results is guaranteed between exhaustivity and accuracy thanks to the proper use of Boolean operators and an iterative search process.

Taxonomy

Studied areas

As interaction between public infrastructure and the automotive industry is at the core of intelligence in the transportation industry, this patent landscape will study both technical fields Autonomous Driving and Smart Transportation for the sake of a more comprehensive view.



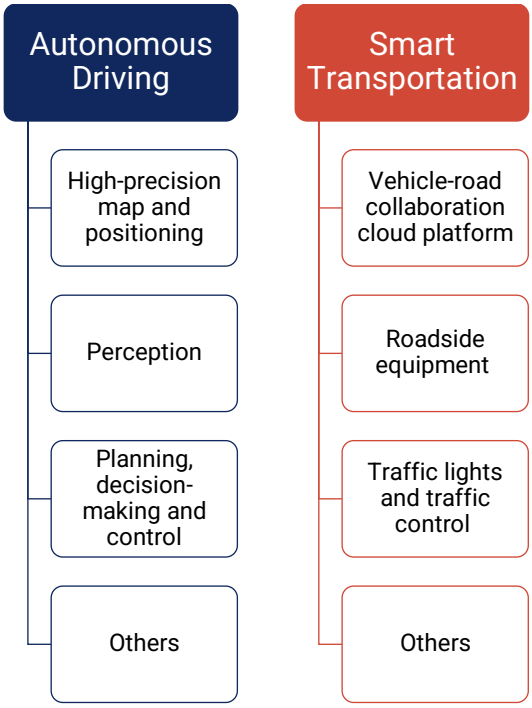
Focus will be on upper levels of vehicle autonomy (SAE Level 4 and Level 5) where human intervention is minimal or totally absent.

Definition of the taxonomy to segment the patent dataset

As stated previously, the study was conducted on two different axes:

- **Autonomous Driving:** Focusing on the autonomous driving high-level intelligence features of vehicles
- **Smart Transportation:** Aiming the intelligence in the evolved transportation systems and infrastructure

Both technical fields contain a wide range of concepts. The analysis was performed on both subjects' general aspects with a more focused study on different segments. The selection of segments' subjects was based on their importance to the fields and on their high contribution in the actual R&D activities. However, this selection is not exhaustive; developments and innovation are also taking place in other domains such as communications, Artificial Intelligence, and others.



Autonomous Driving:

- **High-precision map and positioning:** High-precision positioning, over-the-horizon sensing, lane-level path planning, and other services provided by the high-precision map
- **Perception:** Sensing technology relying on sensors (lidar, cameras, and radar) and massive centralized computing
- **Planning, decision-making and control:** Path planning, decision-making and motion controlling technologies
- **Others:** Other technologies such as connectivity and data transmission

Smart Transportation:

- **Vehicle-road collaboration cloud platform:** Cloud computing traffic related services
- **Roadside equipment:** Intelligent driving roadside devices used to assist vehicle driving
- **Traffic lights and traffic control:** Intelligent traffic lights processing traffic information and managing Intersections' traffic congestion and traffic overflow
- **Others:** Other technologies part of the development of Smart Transportation

Patent landscape

Autonomous Driving

Filing trends

A rise in growth

The period of analysis for this report was limited to the period from 2010 to October 2022. 48,869 patent families related to autonomous driving were detected during this period.

The trend of technology investment over the last few years, namely from 2010 to 2020[1], is illustrated by the graph below, which clearly shows the increase in patenting activity:

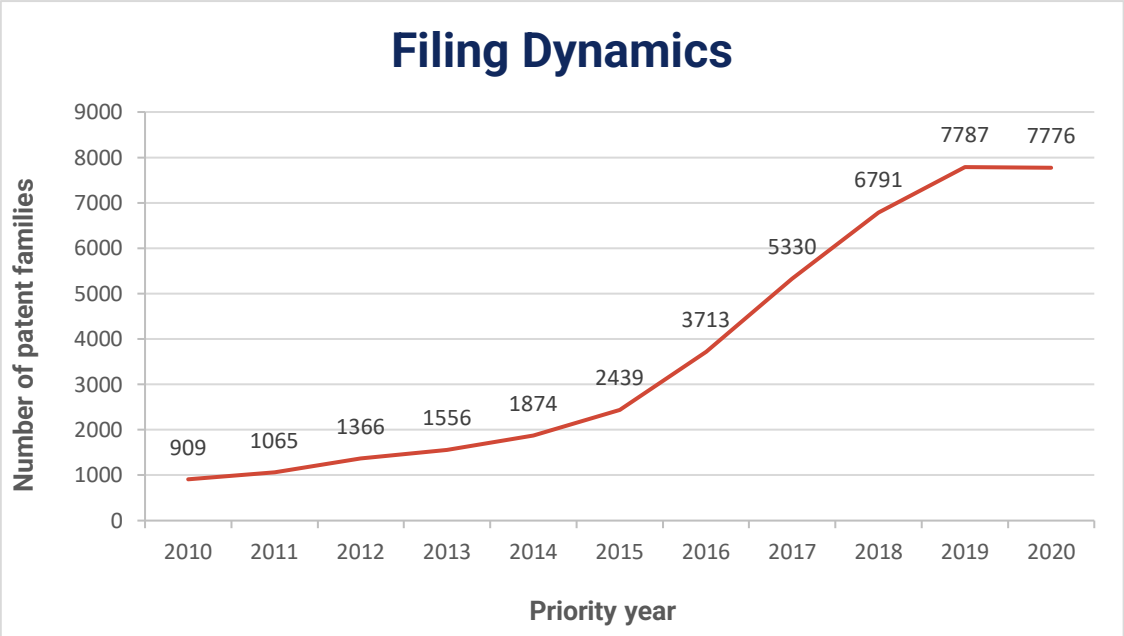


Figure 3 – AD Filing dynamics

Patent applications for autonomous driving are experiencing an acceleration in the number of new filings since 2010. The CAGR* of up to 24% between 2010 and 2020 indicates that this field is expanding rapidly. In addition, many new patent filings are expected in the coming years (many of which are still unpublished).

[1]Due to the delay between the priority filing of a patent and its publication by patent offices, usually 18 months, the last complete year of information used in the current report is 2020.

Patent landscape

Autonomous Driving

Inventions' origin

Nearly half of all patent filings belong to China

Priority country data relates to the amount of patent families which was first filed in a country. It usually contains information on the patenting strategy in the sector and is a strong indicator of the main R&D locations, as most players apply for priority patents locally.

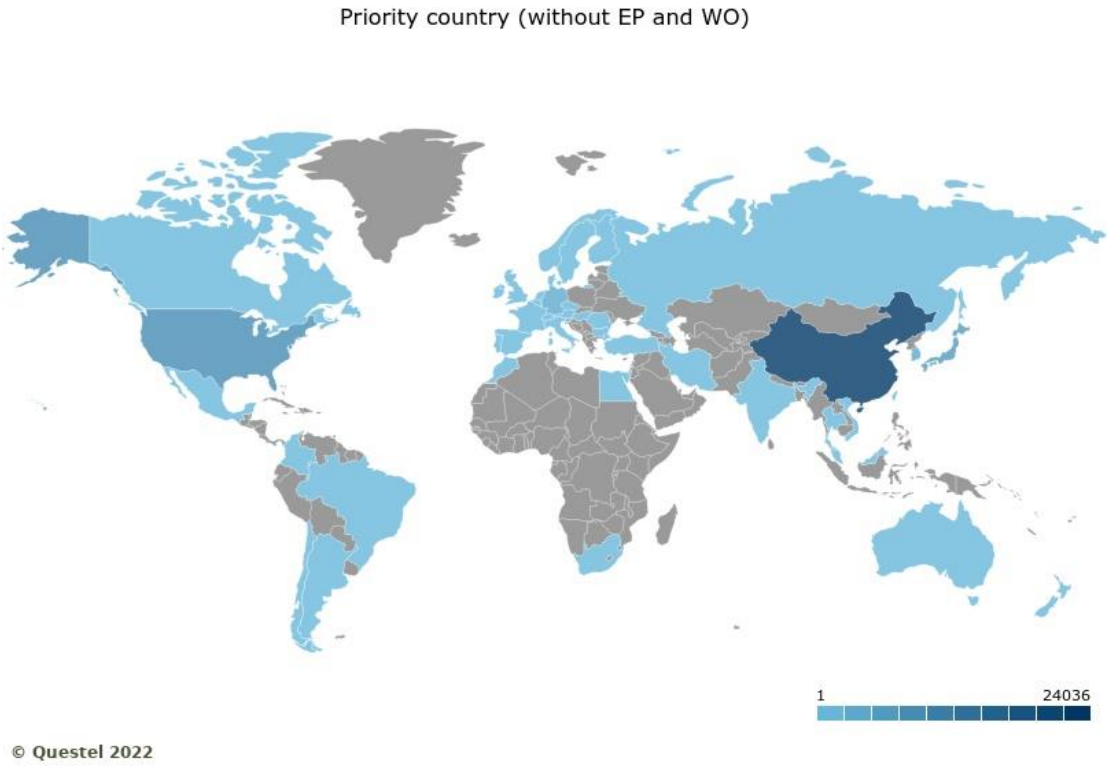


Figure 4 – AD Worldwide patent families by priority country

Overall, about 49.18% of the autonomous driving-related patent applications filed worldwide over the past 10 years came from China, whereas only 17% were from the United States. Japan contributed with 10.9% of the total filings, followed by Germany and South Korea with 8.3% and 8%, accordingly.

In 2010, China's patent applications represented 28% of global patent filings; by 2020, half of autonomous driving-related patent applications came from China; and by 2021, this percentage exceeded two-thirds, about 78%.

Patent landscape

Autonomous Driving

Market countries

China, the main market country

The number of documents published in the various national offices reflects the patent strategies of the actors in the sector, as the national filings are a good indicator of the markets that need to be protected. Please note that some players also target a protection in the geographical areas where the manufacturing sites of their competitors are located. The graph below is based on patent publication numbers in the different Offices.

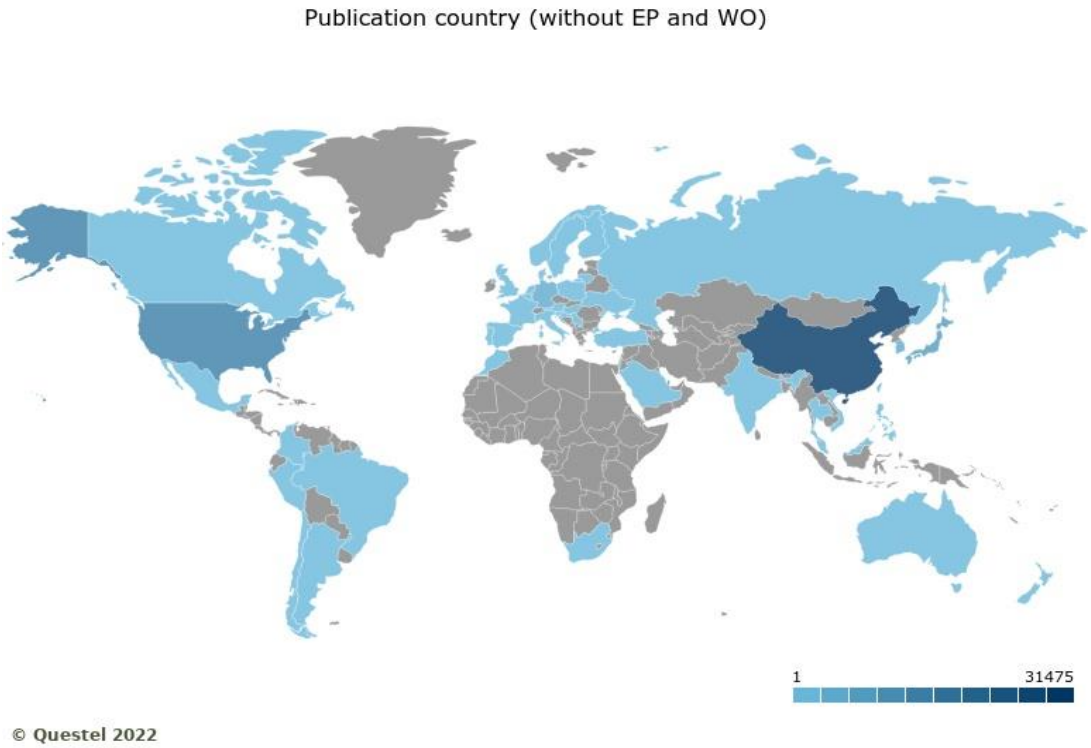


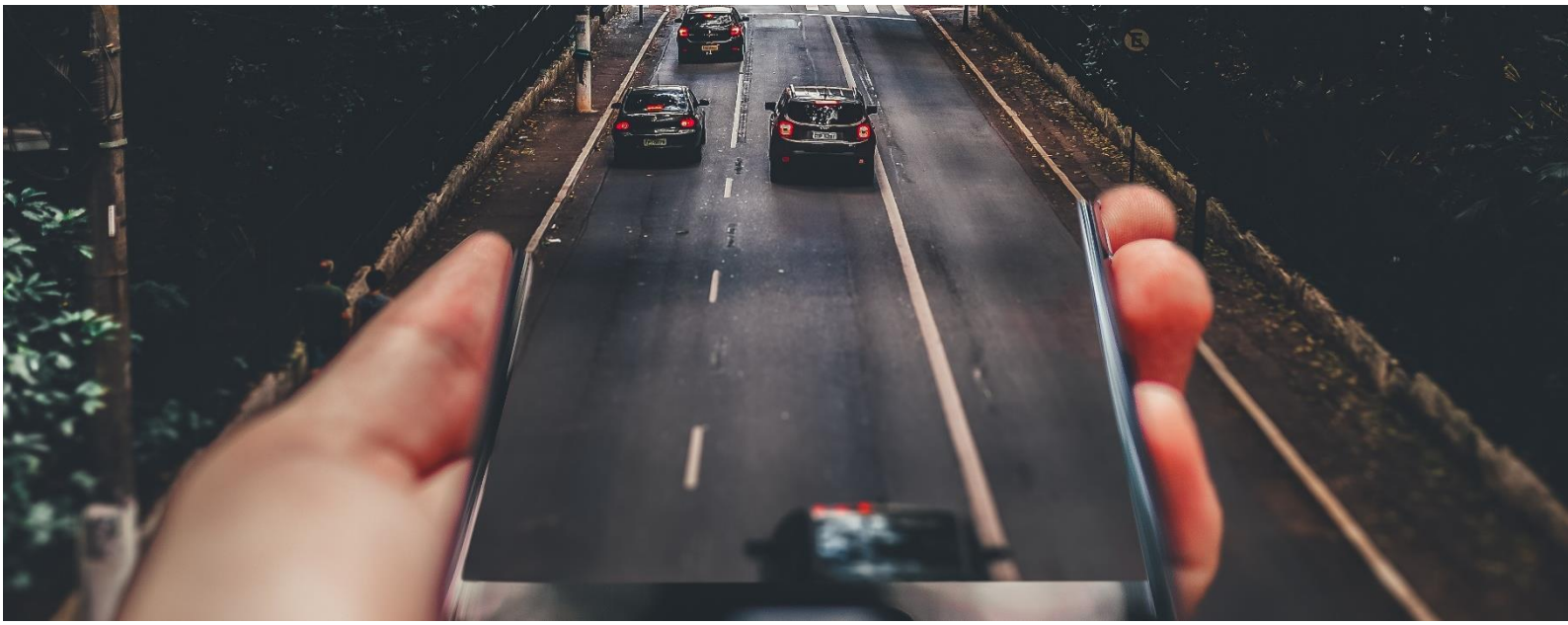
Figure 5 – AD Worldwide patent families by publication country

From the previous analysis, it is to be expected that China is going to offer a large size market for autonomous driving. 64% of the patent publications were published in China, which shows its position as the leading market. This status is further strengthened by the intensity of patent filings from China. The United States comes after with 28%, followed by 15% in Japan, and 12% in Germany.

Patent landscape

Autonomous Driving

Players



China, USA, Japan, and Germany unsurprising domination

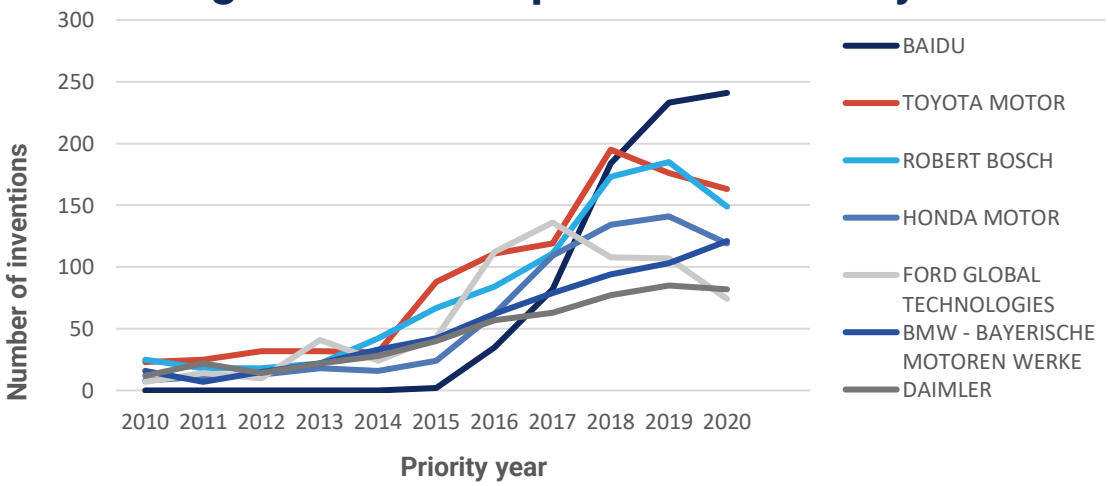
Google, Qualcomm, Mobileye, Uber, Baidu are not among the usual suspects in the automotive industry, but as early as the mid-2010s, they appear in the top 50 autonomous driving patent applicants. These top 50 applicants, led by names like Ford, Toyota, and Bosch, generated about half of the total patents. Non-automotive players also appear in the list of top patent players. Google and its self-driving vehicle subsidiary Waymo occupy the top ten spots, with more than 150 patents, ahead of automakers like Nissan, BMW, and Hyundai. They are followed by other companies like Uber and Delphi, which each hold about 60 patents and tie for 30th place.

TOP 50 APLLICANTS LIST			
Assignees	Number of inventions	Country	Player Typography
BAIDU	1193	China	Internet and technology
TOYOTA MOTOR	1066	Japan	Automotive manufacturer
ROBERT BOSCH	923	Germany	Automotive supplier
HONDA MOTOR	722	Japan	Automotive manufacturer
FORD GLOBAL TECHNOLOGIES	700	USA	Automotive manufacturer
BMW - BAYERISCHE MOTOREN WERKE	621	Germany	Automotive manufacturer
DAIMLER	585	Germany	Automotive manufacturer
HYUNDAI MOTOR	567	South Korea	Automotive manufacturer
GM GLOBAL TECHNOLOGY OPERATIONS	528	USA	Automotive manufacturer
LG ELECTRONICS	453	South Korea	Electronics company
DENSO	444	Japan	Automotive supplier
VOLKSWAGEN	411	Germany	Automotive manufacturer
WAYMO	402	USA	Automotive manufacturer
KIA MOTORS	398	South Korea	Automotive manufacturer
AUDI	358	Germany	Automotive manufacturer
HERE GLOBAL	340	USA	Automotive map solution and location service
HUAWEI	335	China	Telecommunication
NISSAN MOTOR	309	Japan	Automotive manufacturer
CHONGQING CHANGAN AUTOMOBILE	305	China	Automotive manufacturer
ZHEJIANG GEELY HOLDING GROUP	301	China	Automotive manufacturer
CHINA FIRST AUTOMOBILE WORKS (FAW)	300	China	Automotive manufacturer
ZF FRIEDRICHSHAFEN	269	Germany	Automotive supplier
UATC	255	USA	Software services
ZOOX	248	USA	Automotive manufacturer
HYUNDAI MOBIS	233	South Korea	Automotive manufacturer
MITSUBISHI ELECTRIC	220	Japan	Automotive supplier
SUBARU	216	Japan	Automotive manufacturer
TSINGHUA UNIVERSITY	191	China	Academic
PANASONIC INTELLECTUAL PROPERTY MANAGEMENT	161	Japan	Electronics company
PSA AUTOMOBILES	161	France	Automotive manufacturer
JILIN UNIVERSITY	159	China	Academic
INTEL	154	USA	Chip manufacturer
GM CRUISE HOLDINGS	143	USA	Automotive manufacturer
RENAULT	143	France	Automotive manufacturer
SAMSUNG ELECTRONICS	139	South Korea	Electronics company
HITACHI ASTEMO	138	Japan	Automotive supplier
MOTIONAL	138	USA	Automotive manufacturer
WUHAN KOTEI BIG DATA	137	China	Software services
TENCENT TECHNOLOGY SHENZHEN	135	China	Conglomerate
CONTINENTAL AUTOMOTIVE	130	Germany	Automotive parts manufacturer
MAZDA MOTOR	130	Japan	Automotive manufacturer
IBM	129	USA	Computer hardware, software and services
QUALCOMM	128	USA	Telecommunication, Chip manufacturer
VALEO SCHALTER & SENSOREN	119	France	Automotive supplier
APTIV TECHNOLOGIES	114	USA	Automotive technology supplier
CHONGQING UNIVERSITY	114	China	Academic
GUANGZHOU WERIDE TECHNOLOGY	114	China	Automotive supplier
TONGJI UNIVERSITY	114	China	Academic
ZHIDAO NETWORK TECHNOLOGY BEIJING	112	China	Academic
JIANGSU UNIVERSITY	106	China	Academic

Table 1 – Top 50 Applicants of AD-Related Patents

A total of 15% of patents are owned by the top 10 players. The most prolific is Baidu. The Internet giant, which develops maps for navigation, is also developing artificial intelligence for providing autonomous driving solutions. Most importantly, it has set up the Apollo platform for autonomous driving, on which many partners are collaborating. The Chinese Internet giant claims to have driven 32 million kilometers[1] (compared to more than 20 million for Waymo in the U.S. on the road), in 1,000 vehicles.

The leaders are BAIDU with nearly 2.5% of the world patent filing ratio, equivalent to 1193 patents, followed by the Japanese automobile manufacturer, Toyota with thousands of patents, representing 2% of all patents in this field. Next comes ROBERT BOSCH with 1.8%. HONDA is ranked fourth with 722 patents related to autonomous driving (~1.4% of total patents). Automotive companies from Germany such as BMW - BAYERISCHE MOTOREN WERKE and DAIMLER contribute with 1.4% and 1.2% respectively. Coming behind is the South Korean automotive company HYUNDAI MOTOR with 567 patents, contributing 1.1% of the global autonomous driving-related patents rate.



Remark: Some companies ask early publication of their patents in order to rapidly fill the prior art space and block their competitors' future patents. This explains the high number of patents filed in 2020 for some players. The decrease observed for other players in 2020 may be more related to the traditional 18 months delay before publication.

Figure 6 – AD Filing Dynamics – Top 7 players

All top 7 companies have followed approximately the same rapid increase of patent filings from 2010 until 2020, however, BAIDU's filing trend is quite remarkable as it has staringly raised starting 2015.

[1] https://www.autofutures.tv/topics/baidu-granted-china-s-first-ever-permits-for-commercial-fully-driverless-ride-hailing-services/s/8965b372-02c5-442d-b9bb-8dfc69195f45

Patents portfolio's strength and impact

Patent citations, technological diversity, technical domain, patent remaining life, degree of novelty, and market coverage are all some indicators that can be used as a measure of firms' technological capabilities and performance.

Using those indicators, comparison between competitors in terms of technological impact and portfolio value is possible.

Referring to metrics in the following graph (*Figure 7 - Autonomous Driving Player's Impact*) it can be deducted that:

- Baidu owns a strong portfolio value among identified competitors in the field of autonomous driving systems, closely followed by Toyota. Ford, Honda and Robert Bosch follow with lesser indicator's value.
- Ford is a trendsetter in terms of technological impact and is trailed by Baidu.
- Baidu, Toyota, Robert Bosch, Honda, and Ford, all these players seem to cover a wide range of breakthrough technologies in their innovation strategies when it comes to the broad spreading of cited IPC/CPC subclasses in their patent portfolio.

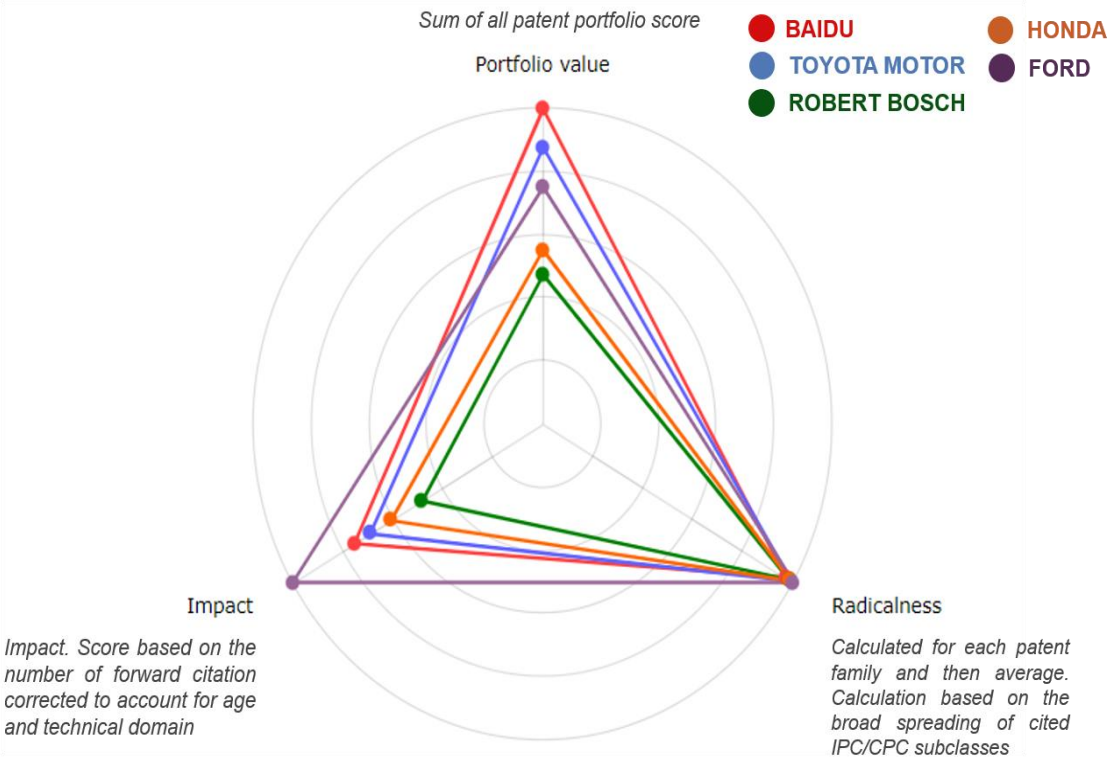


Figure 7 – Autonomous Driving Player's Impact

Analyzing more closely the patents portfolios of some top actors, the technical influence of player's innovation activities and its importance in the technical domain can be spotted. The table below (*Table 2 - Autonomous Driving Impactful patents per actor*), displays in detail this impact, where:

- **Impactful patent** is the count of patent families with at least one non-self forward citation.
- **Interfering patents** is the count of patent families cited by an examinator for questioning the patentability or inventive of a patent application
- **Forward X** is the count of patent families cited by an examinator as category "X"
- **Forward Y** is the count of patent families cited by an examinator as category "Y"

	Impactful patent	Interfering patents	Forward X	Forward Y
BAIDU	741	389	219	314
TOYOTA MOTOR	668	315	185	269
ROBERT BOSCH	502	196	128	139
HONDA MOTOR	423	191	101	165
FORD GLOBAL TECHNOLOGIES	561	265	173	212
BMW	314	128	90	84
DAIMLER	297	96	66	73
HYUNDAI MOTOR	334	104	60	80
GM GLOBAL TECHNOLOGY OPERATIONS	426	189	128	146
LG ELECTRONICS	258	86	49	70
DENSO	284	163	105	141
VOLKSWAGEN	204	82	59	63
WAYMO	295	149	107	128
AUDI	232	104	79	71
HERE GLOBAL	276	71	54	51
HUAWEI	187	83	53	57
NISSAN MOTOR	200	103	58	87
CHONGQING CHANGAN AUTOMOBILE	96	54	31	47
CHINA FIRST AUTOMOBILE WORKS (FAW)	117	61	36	49
ZHEJIANG GEELY HOLDING GROUP	212	160	85	145

Table 2 – Autonomous Driving Impactful patents per actor

The top position of Baidu followed by Toyota is not only marked by the number of patent families but by the impact and the value of their portfolios. Ford 5th position in terms of inventions number is faced with a stronger ranking in terms of portfolio technical impact.

An area of little aggression so far

Only 17 infringement litigations were observed, in the US, Germany, China, and Italy. Out of almost 50,000 patent families, this number is incredibly low and represents a percentage of 0.03% of the total patents in this field. This very low level of patent litigation is correlated with the technology field's low maturity, indicating that numerous technologies are not yet commercialized, and also that market players are racing each other on technology performance and data volumes to win market share. The patent litigations could come later when the market growth decelerates.

Patent landscape

Smart Transportation

Filing trends

A high growth

This report analysis timeframe was limited to the period starting from 2010 till October 2022. 35 858 patent families of Smart Transportation related patent families were detected in this timespan.

The technology investment trend during the last years, namely from 2010 to 2020[1] can be depicted in the following graph clearly displaying the increase in patenting activities:

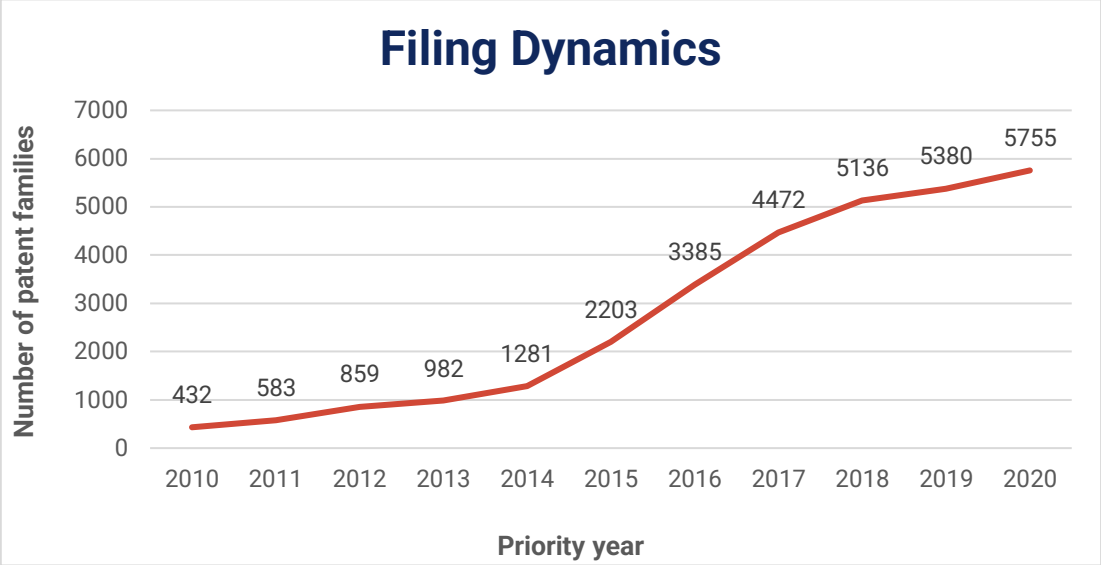


Figure 8 – ST Filing Dynamics

The high growth rate in the last years can reflect the impact of emerging technologies such as IoT and 5G communication on this field. The CAGR value recorded between 2014 and 2020 was 28%, a value that displays a strong position for Smart Transportation among other new generation technologies.

Patent landscape

[1] Due to the delay between the priority filing of a patent and its publication by patent offices, usually 18 months, the last complete year of information used in the current report is 2020.

Smart Transportation

Inventions' origin

Asian dominance: The biggest patent filings number for China and the highest growth rate for South Korea

Priority country data may be used to indicate the main R&D locations, as most players file their first patent applications locally.

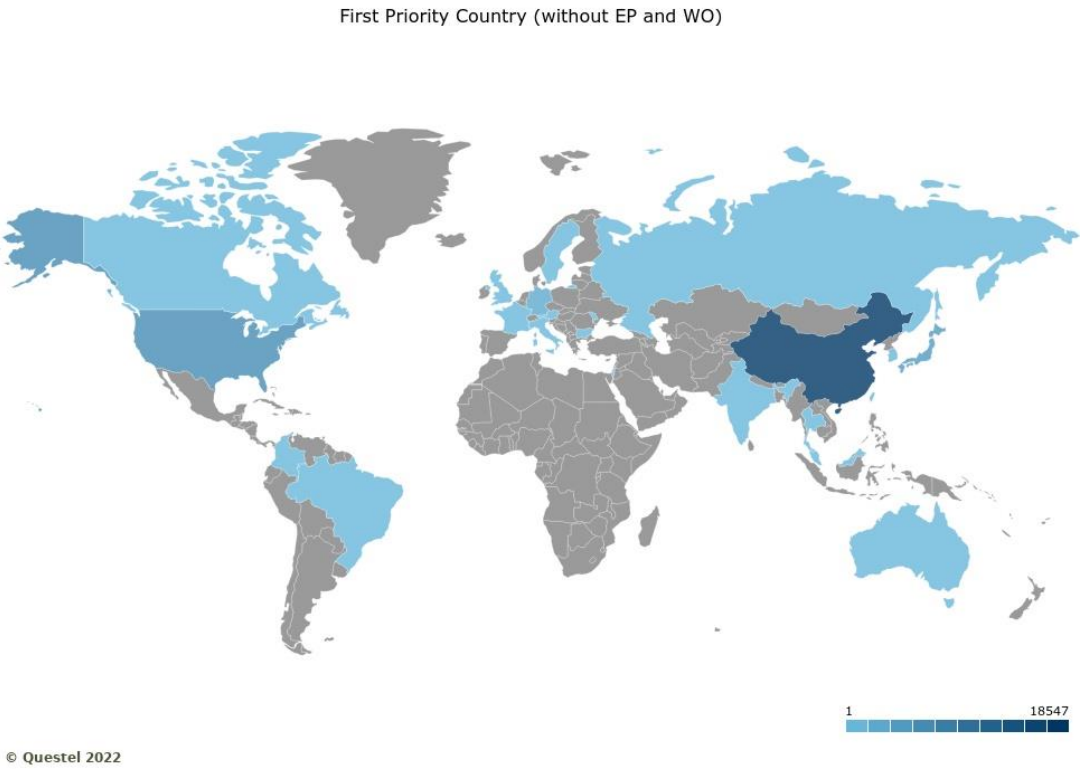


Figure 9 – ST Worldwide Patent Filing Countries

Analyzing the dynamics from 2010 to 2020, it was noticed that 46% of Smart Transportation related filing activities were in China. 19% of the global patent filing activity was attributed to the US followed by 14% for Japan. Europe highest contribution was associated to Germany with an 8% share, while South Korea came after with just 6%.

Patent landscape

Smart Transportation

Market countries

China, main market country

Publication countries is one of the indicators that reflects targeted markets by different players, markets that need to be protected as per the players' protection strategy. However, the publication geographical areas may not be restricted to just potential markets, they may also represent the location of competitors manufacturing sites where inventions need also to be protected. The map below represents the number of published patent families per area depending on the Offices practices.

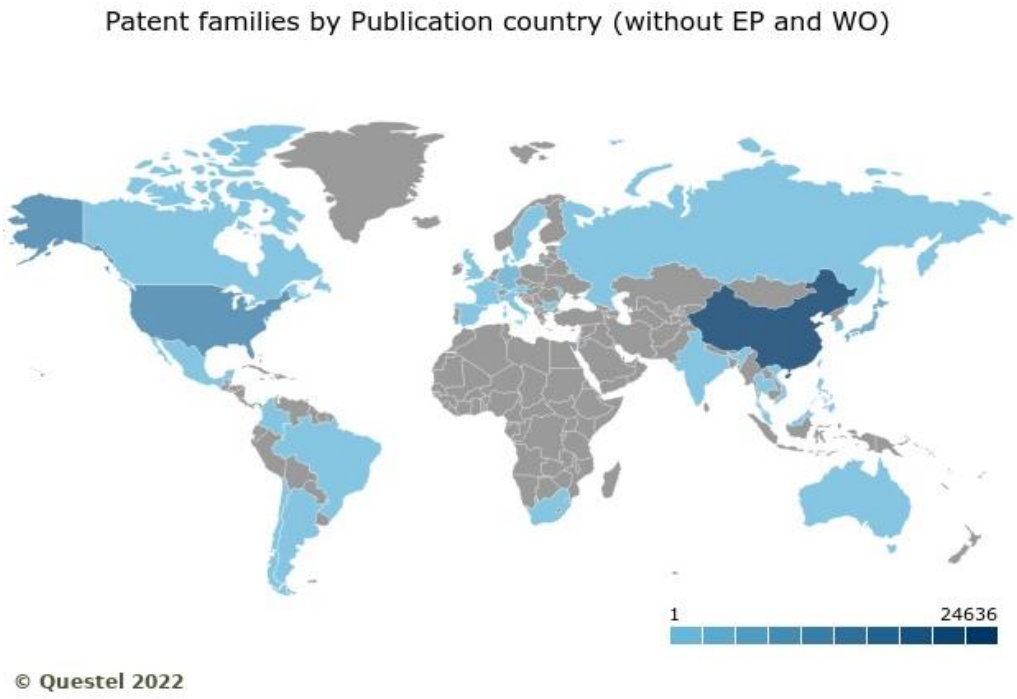


Figure 10 – ST Worldwide patent families by publication country

38% of patent families have been published in China, a number that demonstrates the importance of China as major market. However, this high percentage is also strengthened by the big Chinese patent activity as seen in the previous section[1], where 46% of Smart Transportation related filing activities comes from China. USA and Japan follow with 17% and 10% respectively.

Patent landscape

Smart Transportation

[1] Refer to the First Priority Country graph

Players

35% of total inventions in Smart Transportation comes from the top 50 players (12,683 patent families) and 17% from the top 10 (6,187 patent families). The domination of automotive specialized or related activities companies is obvious in the field with 30 players out of 50. The share of the academic in the top 50 is restricted to 10 players, all Chinese, which could be a sign of the maturity of this field and an indication of a great interest of the industry in this extremely high trendy domain, where many projects have been launched in different countries. Moreover, the interest in the field is spread over different geographic areas with 16 Chinese players (including 10 academic), 11 American (all industrial), 9 Japanese, 6 German and 4 South Korean. The variety in players typography can also be noticed as electronics, semi-conductor, Internet and telecommunications, among others, are all major key technology fields for smart transportation.

The top patent filer in smart transportation is the Japanese automotive manufacturer Toyota with 3.6% of total number of patent families. This number reflects the high investment of the company in the field. Toyota's smart city project the Woven City[1], with the construction inaugurated in January 2021, is another proof of the extremely high ambitious goals of the company. The Chinese giant, Baidu second position with 2.8% share of inventions is not less important and reflects its leading position in smart transportation as it is for autonomous vehicles with Baidu Apollo high involvement in three major fields, autonomous driving, smart cars and smart transportation. This number mirrors the company's vision[2] as to become a global leader in the intelligent driving industry.

Among the top 10 players, 3 come from outside the automotive industry: BAIDU is second, LG ELECTRONICS is 7th and HUAWEI 8th with a global share of patent families of 2.8%, 1.4% and 1% respectively. The tight race between countries can be also clearly noticed with the diversity of top players, Japanese, Chinese, American and German.

[1] https://www.woven-city.global/
[2] https://www.apollo.auto/aboutus

TOP 50 APPLICANTS LIST			
Assignees	Number of inventions	Country	Player Typography
TOYOTA MOTOR	1293	Japan	Automotive manufacturer
BAIDU	1013	China	Internet and technology
HONDA MOTOR	664	Japan	Automotive manufacturer
ROBERT BOSCH	620	Germany	Automotive supplier
FORD GLOBAL TECHNOLOGIES	566	USA	Automotive manufacturer
DENSO	511	Japan	Automotive supplier
LG ELECTRONICS	489	South Korea	Electronics company
HUAWEI	359	China	Telecommunications
GM GLOBAL TECHNOLOGY OPERATIONS	351	USA	Automotive manufacturer
BMW - BAYERISCHE MOTOREN WERKE	321	Germany	Automotive manufacturer
NISSAN MOTOR	310	Japan	Automotive manufacturer
HYUNDAI MOTOR	304	South Korea	Automotive manufacturer
DAIMLER	299	Germany	Automotive manufacturer
WAYMO	291	USA	Automotive manufacturer
VOLKSWAGEN	260	Germany	Automotive manufacturer
AUDI	245	Germany	Automotive manufacturer
SOUTHEAST UNIVERSITY	227	China	Academic
MITSUBISHI ELECTRIC	224	Japan	Automotive supplier
PANASONIC INTELLECTUAL PROPERTY MANAGEMENT	214	Japan	Electronics company
TENCENT TECHNOLOGY SHENZHEN	194	China	Internet and Technology
TSINGHUA UNIVERSITY	193	China	Academic
TONGJI UNIVERSITY	176	China	Academic
INTEL	169	USA	Chip manufacturer
SUBARU	168	Japan	Automotive manufacturer
JILIN UNIVERSITY	165	China	Academic
CHONGQING UNIVERSITY	163	China	Academic
KIA MOTORS	160	South Korea	Automotive manufacturer
CHANG'AN UNIVERSITY	145	China	Academic
BEIJING UNIVERSITY OF TECHNOLOGY	142	China	Academic
HERE GLOBAL	142	USA	Automotive map and location solution
ZOOX	141	USA	Automotive manufacturer
VALEO SCHALTER & SENSOREN	140	France	Automotive supplier
RENAULT	136	France	Automotive manufacturer
HYUNDAI MOBIS	131	South Korea	Automotive supplier
CHONGQING CHANGAN AUTOMOBILE	130	China	Automotive manufacturer
ZF FRIEDRICHSHAFEN	124	Germany	Automotive supplier
BEIHANG UNIVERSITY OF AERONAUTICS & ASTRONAUTICS	123	China	Academic
JIANGSU UNIVERSITY	122	China	Academic
GENVICT	116	China	Intelligent transportation services
MOTIONAL	116	USA	Automotive manufacturer
UATC	115	USA	Software services
VENIAM	114	USA	Internet of Moving Things
PSA AUTOMOBILES	109	France	Automotive manufacturer
QUALCOMM	105	USA	Telecommunications, Chip manufacturer
HITACHI ASTEMO	104	Japan	Automotive supplier
APTIV TECHNOLOGIES	100	USA	Automotive technology supplier
ZHEJIANG GEELY HOLDING GROUP	98	China	Automotive manufacturer
WUHAN UNIVERSITY OF TECHNOLOGY	95	China	Academic
PIONEER ELECTRONIC	94	Japan	Electronics company
IBM	92	USA	Computer hardware,software and services

Table 3 – Top 50 Applicants of Smart Transportation -Related Patents

Increase in patent filings trends for the top 5 players can be observed between 2013 and 2015. While ROBERT BOSCH number of inventions steep increase started in 2013, this trend started 2 years later for BAIDU. TOYOTA MOTORS kept its leadership in number of yearly patents with a high growth rate of 24% between 2015 and 2020. Despite this first position for TOYOTA, the appearance of BAIDU who was almost absent before 2014 is quite impressive, where an explosive growth of 119% was registered from 2015 to 2020. This extremely high growth demonstrates the high investment of the company in the field and reflects the Chinese government new policies[1] to create a favourable environment for smart transportation development. Those policies helped to foster new initiatives and projects that work on accelerating the deployment of Smart Transportation in the country.

The lowest CAGR rate registered for the top 5 industrials is for ROBERT BOSCH with only 5% (2015-2020). FORD decline in filing activities was noticed starting 2018 despite a growth rate of 8% between 2015 and 2020. HONDA's peak increase was in 2016 where the number of filings was more than 10 times the previous year. HONDA's investment in Smart Transportation is also important where a CAGR of 42% was registered for the company for the same period (2015-2020).

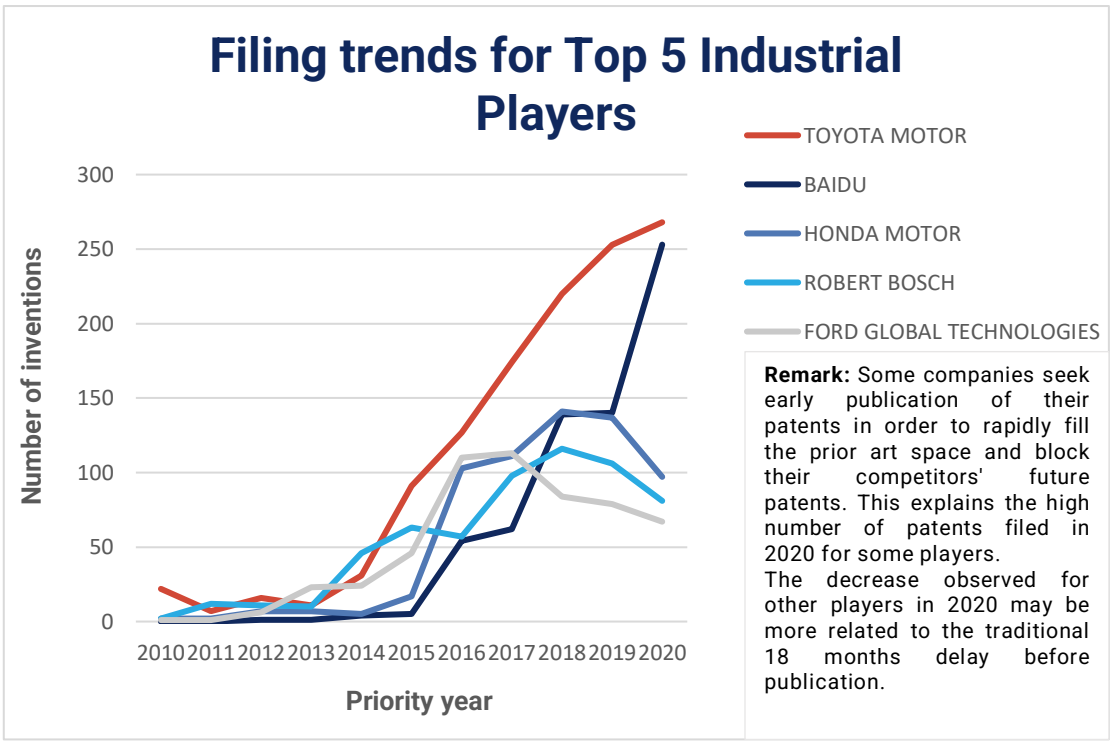


Figure 11 – ST Top 5 Industrial Players Filing Trends

[1] http://civitas.eu/news/smart-transportation-in-china-what-is-the-current-situation

Patents portfolio's strength and impact

The same indicators (Patent citations, technological diversity, etc.) used in evaluating technological capabilities and performance for Autonomous Driving actors, are used as a measure to assess the positions of firms in smart Transportation.

Comparing competitors' technological impact and portfolio value by referring to the following graph (*Figure 12 - Smart Transportation Player's Impact*) shows that:

- Toyota holds the highest portfolio value across all competitors identified in the Smart Transportation field, closely followed by Baidu. The tight competition between Toyota and Baidu can't but be noticed when it comes to the first two positions in Autonomous Driving and Smart Transportation. The same actors, Ford, Honda and Robert Bosch follow with lesser indicator's values as it was for self-driving.
- Ford being the pioneer in terms of impact is remarkable as again the company is holding the highest technological impact ranking as it was for Autonomous Driving.

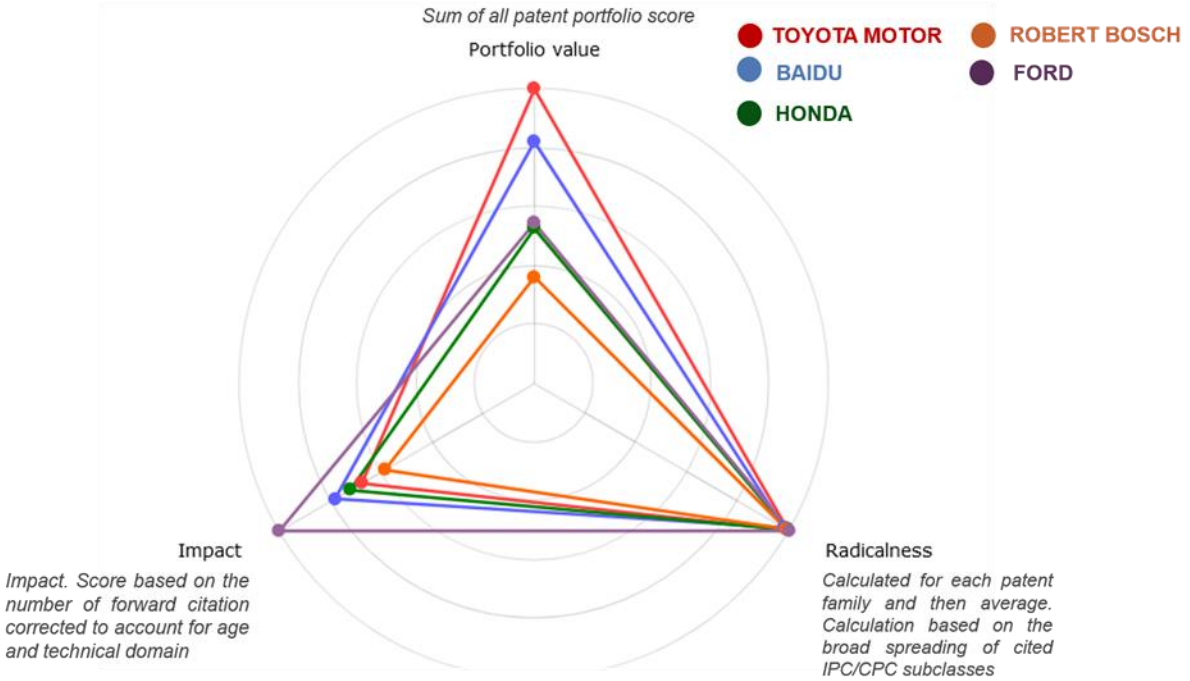


Figure 12 – Smart Transportation Player's Impact

A closer analysis of top actors' patents portfolios technical influence (*Table 4 - Smart Transportation Impactful Patents per actor*), Toyota, with its long history in the field, holds again the top position. Baidu's newest entry does not only mark the field with the big number of filing and its growth rate, but also with the value and the impact of the company's inventions in the innovation world.

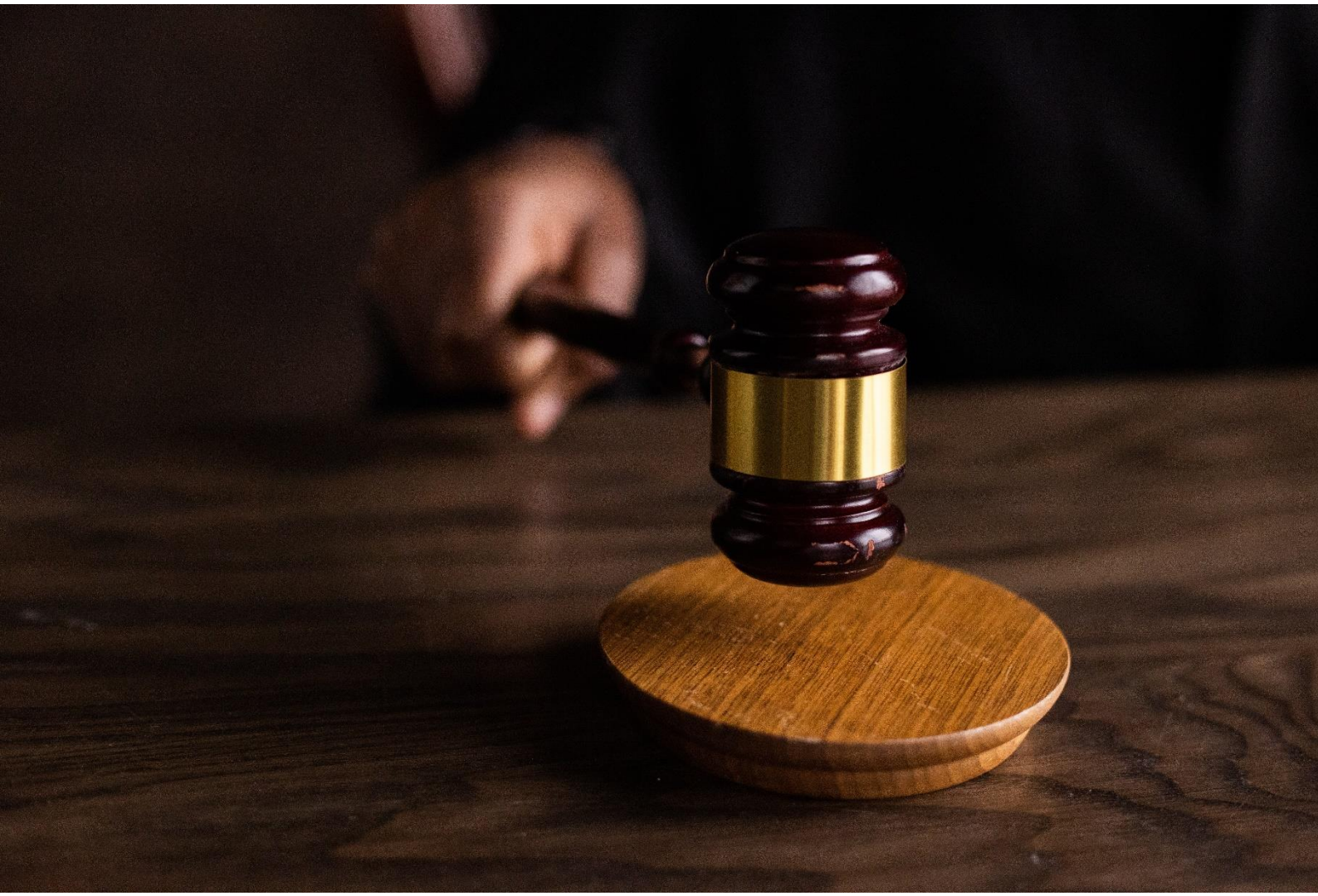
- **Impactful patent** is the count of patent families with at least one non-self forward citation.
- **Interfering patents** is the count of patent families cited by an examinator for questioning the patentability or inventive of a patent application
- **Forward X** is the count of patent families cited by an examinator as category "X"
- **Forward Y** is the count of patent families cited by an examinator as category "Y"

	Impactful patent	Interfering patents	Forward X	Forward Y
TOYOTA MOTOR	753	355	228	308
BAIDU	552	305	184	251
HONDA MOTOR	439	246	135	219
ROBERT BOSCH	377	169	118	125
FORD GLOBAL TECHNOLOGIES	454	236	158	198
DENSO	322	208	134	188
LG ELECTRONICS	324	125	86	96
HUAWEI	225	108	81	74
GM GLOBAL TECHNOLOGY OPERATIONS	343	153	119	126
BMW - BAYERISCHE MOTOREN WERKE	183	73	48	50
NISSAN MOTOR	230	129	80	114
HYUNDAI MOTOR	191	66	43	49
DAIMLER	155	53	29	44
WAYMO	242	135	107	119
VOLKSWAGEN	174	76	61	55
AUDI	165	71	53	60
SOUTHEAST UNIVERSITY	151	73	31	65
MITSUBISHI ELECTRIC	131	86	48	78
PANASONIC INTELLECTUAL PROPERTY MANAGEMENT	145	91	50	80
TENCENT TECHNOLOGY SHENZHEN	91	41	27	35

Table 4 – Smart Transportation Impactful Patents per actor

Unaggressive field

Only 11 infringement related litigations have been observed out of around 36 K patent families, 6 in the US, 4 in Germany and 1 in China. A very low number when compared to the total number of patent families and to number of infringements in other technical fields. This number may be predisposed to increase when Smart Transportation is widely deployed. Litigation may be even wider when considering that inventions don't just come from traditional car manufacturers and suppliers but rather involves a variety of technical fields such as IT and telecommunications.



Appendices

ANNEX A – TAXONOMY

Technology segments explained

High-precision map and positioning	A High-precision map called also high-definition map (HD map) is a highly accurate map used in autonomous driving, containing details not normally present on traditional maps. Such maps can be precise at a centimetre level. HD maps are often captured using an array of sensors, and GPS. High-definition maps for self-driving cars usually include map elements such as road shape, road marking, traffic signs, and barriers.
Perception	The perception in self-driving cars consist of using a combination of high-tech sensors, such as thermographic cameras, radar, lidar, sonar, GPS, odometry and inertial measurement units, to perceive the environment around the vehicles, in real-time.
Planning, decision-making and control	Planning, decision-making and motion control consist of using data from the HD map and the perception units to form the basis for generating a trajectory that serves as a target value to be followed by a controller.
Vehicle-road collaboration cloud platform	It is a web-based traffic management ecosystem that accesses, monitors, and manages the massive amounts of data generated to deal with the traffic challenges present in smart city environments and more specifically in smart transportation.
Roadside equipment	Roadside equipment are used to assist vehicle driving in having a more comprehensive environmental information and therefore enhance prediction's accuracy.
Traffic lights and traffic control	Smart traffic lights or Intelligent traffic lights are a vehicle traffic control system that combines traditional traffic lights with an array of sensors and artificial intelligence to intelligently route vehicle and pedestrian traffic.

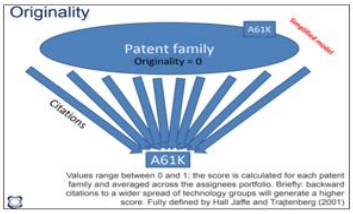
Industries explained

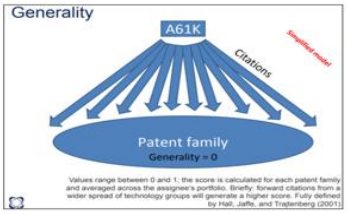
Transportation	Automobiles, vehicles, Autonomous Vehicle, (AV), Autonomous Driving (AD) etc.
Telecommunications	3G, 4G, 5G networks, Internet of Things (IoT), Vehicle-to-Vehicle (V2V), Vehicle-to-Everything (V2X) etc.
Internet, search engine& software services	Software systems, Operating systems, Cloud computing, Servers, Databases etc
Electronics	Electronic devices, Microprocessors, Chips manufacturing, Integrated circuit, Sensors etc.
Computer	Hardware, Digital machine, peripheral equipments etc

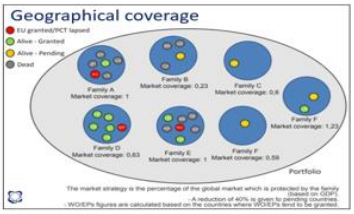
ANNEX B – GLOSSARY

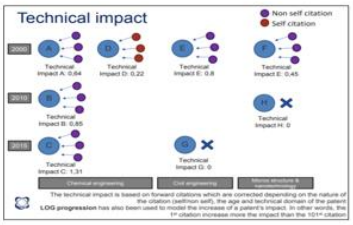
- **Patent family (Fampat)**: defined as an "invention-based family", this family definition from Questel incorporates the EPO's strict family rule (same priority application(s)) with additional rules (applications falling outside the 12 months filing limit; links between EP and PCT publications…) etc. A reasonable compromise between strict family and extended family.
- **Patent application**: to obtain a patent, an application must be filed in the appropriate Patent Office with all the necessary documents and fees. The patent office will conduct an examination to decide whether to grant or reject the application. Patent applications are generally published 18 months after the earliest priority date of the application. Prior to that publication, the application remains confidential.
- **Granted patent**: once examined by the patent office, an application becomes a granted patent or is rejected. If granted, the patent gives his owner a temporary right for a limited time period (normally 20 years) to prevent unauthorized use of the technology outlined in the patent. Procedure for granting patents varies widely between countries according to national laws and international agreements. Note that in the same patent family, an application can be granted in one country and rejected in another.
- **PCT (WO)**: The Patent Cooperation Treaty (PCT) is an international patent law treaty concluded in 1970, administered by the World Intellectual Property Organization (WIPO), between more than 140 Paris Convention countries. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing a single "international" patent application instead of filing several separate national or regional patent applications. The granting of patents remains under the control of the national or regional patent offices in which is called the "national phase".
- **European patent (EP)**: a European patent can be obtained for all the EPC countries by filling a single application at the EPO in one of the three official languages (English, French or German). European patents granted by the EPO have the same legal rights and are subject to the same conditions as national patents (granted by the national patent office). A granted European patent is a "bundle" of national patents, which must be validated at the national patent office to be effective in member countries. The validation process could include submission of a translation of the specification, payment of fees and other formalities at the national patent office. Once a European patent is granted, competence is transferred to the national patent offices. Other regional patents or procedures also exist: the Eurasian patent (EA), ARIPO patent (AP) for English-speaking Africa and OAPI patent (OA) for French-speaking Africa.

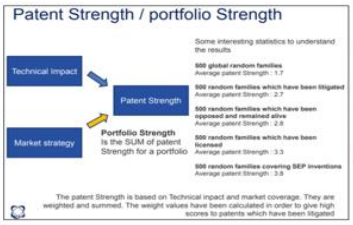
- **Patent classifications**: patent classification is a system for examiners of patent offices or other people to code documents, such as published patent applications, according to the technical features of their content. The International Patent Classification (IPC) is agreed internationally. the European Patent Office (EPO) and USPTO launched a joint project to create the Cooperative Patent Classification (CPC) in order to harmonize the patent classifications systems between the two offices.
- **Patent applicant/assignee**: when a person is applying for a patent, the word "applicant" refers to the assignee, the person to whom the inventor is under an obligation to assign the invention, or the person who otherwise shows sufficient proprietary interest in the matter. We call it also patent owner or patent assignee; typically, it is the inventor's employer.
- **Priority filling**: the first location in which a particular invention has a patent application filed, also known as the office of first filing.
- **Average family size**: average number of granted or pending patents in each patent family in an assignee's portfolio.
- **Geographic coverage**: the total number of granted or pending patents in Tier1 and BRIC regions or countries (Taiwan, Australia, Republic of Korea, China, India, Brazil, France, Germany, Japan, USA).
- **CAGR**: compound annual growth rate, initially used to calculate and determine the rate of investment return, it represents the average annual growth rate between two dates in the study.
- **Technical impact:** The technical impact is based on forward citations which are corrected depending on the nature of the citation (self/non self), the age and technical domain of the patent**.**
- **Portfolio value:** The patent value is based on technical impact and Geographic coverage. They are weighted and summed. The weight values have been calculated in order to give high scores to patents which have been litigated
- **Radicalness:** Calculated for each patent family and then average. Calculation based on the broad spreading of cited IPC/CPC subclasses.
- **Impactful patent** is the count of patent families with at least one non-self forward citation.
- **Interfering patents** is the count of patent families cited by an examinator for questioning the patentability or inventive of a patent application.
- **Category X:** Where a document cited in the European search report is particularly relevant, it is indicated by the letter "X" or "Y". Category "X" is applicable where a document is such that **when taken alone**, a claimed invention cannot be considered novel or cannot be considered to involve an inventive step.
- **Category Y:** Where a document cited in the European search report is particularly relevant, it is indicated by the letter "X" or "Y". Category "Y" is applicable where a document is such that a claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other documents of the same category, such combination being obvious to a person skilled in the art.

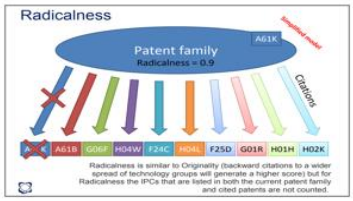












About Questel's Consulting team

Questel's Consulting team combines skills in IP, technology, and market to provide various kind of data-driven projects enabling innovative organizations to make strategic decisions: Patent Landscapes, Tech & Competency mapping, Patent portfolio assessment for pruning or licensing, Technology scouting, etc.

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