

# Research on Innovation System in China's Automobile Industry

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**Abstract:** This study analyzes innovation systems in the automobile industry based on the basic definition of the automobile industry's innovation system. The study demonstrates that non-profit research institutions dedicated to application technology, focusing on technology maturity from levels 4 to 7, and responsible for closing the gap between basic research and industrial technology, are falling short. This study considers international standards and experiences, and examines the structure of the innovation system in China's automobile industry. It recommends the establishment of a Chinese automotive innovation council and an acceleration of the construction of an automobile industry-related innovation center.

**Keywords:** innovation systems; systems and mechanism; strategic consulting; innovation center

The powerful automobile industries of leading automobile producing countries across the world can be essentially ascribed to their state-of-the-art automotive technologies. Additionally, mature and efficient innovation systems assist these countries in maintaining their long-term competitive advantage. The leading automobile producing countries (for example, the U.S., Japan, and Germany) successively develop and implement technological innovation strategies and achieve high levels of industrial development with the intent to boost the competitiveness of their automobile industries and attain sustainable economic development.

In this context, China also resolves to strategically build its automotive innovation systems. In April 2017, the *Medium & Long-term Development Plan for the Automobile Industry* was jointly released by the Ministry of Industry and Information Technology, the National Development and Reform Commission and the Ministry of Science and Technology [1]. This development plan lays out the medium and long-term development roadmap, objectives, and key tasks of China's automobile industry. Building an innovation system is given priority among the six key tasks, and building innovation centers is given priority among the eight key projects. Evidently, building an innovation

system and innovation platform is of great importance to China's automobile power strategy.

## 1 Background

The definitions of innovation vary in different historical periods and from scholar to scholar. In this text, innovation includes technological innovation and non-technological innovation. Technological innovation covers fundamental research, research of applied technologies, and industrialized, technological development (as described in Table 1, they respectively respond to Levels 1 to 3, Levels 4 to 7, and Levels 8 to 10 in the TRL and MRL system specified by the U.S. Department of Defense). Non-technological innovation refers to institutional innovation associated with technological innovation, for example, innovation in business patterns and institutional mechanisms. In this text, the automobile industry innovation system refers to the innovation network formed with certain institutional mechanisms in the process of collaborative innovation by innovative entities (for example, enterprises, colleges, scientific research institutions, social organizations, and governments) in the automobile industry and associated industries.

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**Table 1.** Grading and definitions of TRL and MRL.

TRL	Definition	MRL	Definition
1	Basic principles observed and reported	1	Basic manufacturing implications identified
2	Technology concept and/or application formulated	2	Manufacturing concepts identified
3	Analytical and experimental critical function and/or characteristic proof of concept	3	Manufacturing proof of concept developed
4	Component and/or breadboard validation in laboratory environment	4	Capability to produce the technology in a laboratory environment
5	Component and/or breadboard validation in relevant environment	5	Component and/or breadboard validation in relevant environment
6	System/subsystem model or prototype demonstration in a relevant environment	6	Capability to produce a prototype system or subsystem in a production relevant environment
7	System prototype demonstration in an operational environment	7	Capability to produce systems, subsystems, or components in a production representative environment
8	Actual system completed and qualified through test and demonstration	8	Pilot line capability demonstrated. Ready to begin low rate production
9	Actual system proven through successful mission operations	9	Low rate production demonstrated. Capability in place to begin Full Rate Production
		10	Full Rate Production demonstrated and lean production practices in place

Note: TRL is the abbreviation of “technology readiness level,” and MRL is the abbreviation of “manufacturing readiness level.”

### 1.1 The global automobile industry is facing profound reform, and innovation system development is entering a new stage

As the landmark industry indicative of a country’s economic competitiveness, the automobile manufacturing industry is not only an important force that promotes scientific and technological revolution and industrial reform, but also one of the most active innovation fields in a national economic system. Today, technological breakthroughs have been made successively in the fields of information, energy, materials, and artificial intelligence. These breakthroughs have been quickly integrated into the automobile industry, thus bringing about a profound reform in the form of automotive products and modes of automobile production. There has also been a rapid emergence of new demand and business patterns, and deep adjustment of industrial patterns and industrial ecosystems. Meanwhile, the innovation system for the global automobile industry and the innovation system for the global manufacturing industry system are also undergoing reform, specifically, from linear innovation and system innovation to integrated innovation and cluster innovation. Facing these trends in innovation in the global automobile industry, China’s automobile industry must actively build its innovation system and accelerate the transformation from a follower of innovation to a leader of innovation.

### 1.2 Building an automobile power; “from big to strong” strategies demand an enhancement in innovation

Since the implementation of reform and the opening-up of China’s economy, China’s automobile industry has substantially grown in terms of both industrial scale and overall strength. Ac-

ording to statistics from the China Association of Automobile Manufacturers (CAAM), since 2009, globally, China has ranked first by production and sales volume for nine consecutive years. At present, China’s automobile industry has retained this ranking position globally and in the future, the production and sales size of China’s automobile industry is expected to account for a remarkably higher global proportion (30% currently). Therefore, China has become a genuinely important automobile country. However, China’s automobile industry is still in a stage characterized as “big but not strong,” and has not made an obvious breakthrough in the three elements of an automobile power, among which, technological innovation plays a critical role. First, China has not completely acquired core technologies. Second, China has not successfully developed a number of automobile enterprises or famous brands with international competitiveness. Third, China is still deficient in the ability to utilize both international and domestic resources and to succeed in both international and domestic markets. In particular, the international market share of China’s automobile industry is very low. Among the three elements of an automobile power, the most important priority is technological innovation including the acquisition of core technologies and expedited technological innovation. This provides a basis for the other two elements, and it is an urgent and arduous task for building an automobile power.

### 1.3 An innovation system fosters industrial competitiveness, and the development of an innovation system is urgently needed

In automobile industry innovation systems, non-profit scientific research institutions, colleges, and enterprises constitute the three major pillars. Meanwhile, innovation platforms represent-

ed by innovation centers play a bridging role, serve as pivotal platforms, and offer a link between fundamental research and industrialized, technological development. Building China's automobile industry innovation system must be considered in the context of international competition with the automobile industries of western developed countries and guided by China's automobile power strategy. To turn China into an automobile power in the new era, top-level design and system breakthroughs are particularly important to innovation entities and the development of innovation platforms.

## 2 The status quo of the innovation system in China's automobile industry

### 2.1 Innovation elements have been accumulated to support the innovation of China's automobile industry

The investment into R&D of automobiles in China continues to increase rapidly. According to the statistics of the *China Automotive Industry Yearbook*, the R&D investment of China's automobile industry increased from 16.78 billion yuan to 92.8 billion yuan between 2001 and 2015. The compound annual growth rate (CAGR) of the R&D investment reached 21.8% and was higher than automobile turnover (18.3%). The intensity of R&D investment began to increase from a low and medium level (1% to 2%) to a medium and high level (2% to 5%). In emerging technological fields such as new-energy automobiles, the intensity of R&D investment was even as high as 8% to 10%. The intensity of R&D human input reached at least 9%. Between 2001 and 2015, the population of R&D personnel in China's automobile industry increased from 44,000 to 338,000 and the intensity of R&D human input increased from 2.98% to 9.4%. In 2016, the R&D expenditure per capita reached 274,000 yuan [2], twice as much as in 2001. Evidently, the R&D activities in China's automobile industry are rising.

Meanwhile, a large number of innovation platforms have been set up, including key laboratories, engineering technology centers, and enterprise technology centers. In the automobile industry field, the National Development and Reform Commission along with other governmental agencies have accredited 69 national enterprise technology centers, accounting for 5.4%. The Ministry of Science and Technology has accredited five machinery-related national key laboratories, accounting for 17.2%. In addition, the National Development and Reform Commission has accredited some national engineering laboratories, and the Ministry of Science and Technology has accredited a number of national engineering technology research centers.

### 2.2 The innovation environment continues to improve, and new institutional mechanisms are under exploration

At present, some national level automobile-related scien-

tific and technological projects have been implemented. These include the national special scientific and technological project for new-energy automobiles and the technological innovation project for the new-energy automobile industry. In respect of new-energy automobiles, these projects effectively promote large-scale industry and university research collaboration, assist the industrialization of R&D achievements, cluster the preeminent innovation resources, and promote the rapid development of related technologies. The five major projects specified in *Made in China 2025* and the *Three-year Action Program on Strengthening the Core Competitiveness of Manufacturing Industry (2018 to 2020)* render special support for new-energy automobiles, intelligently networked automobiles, and their critical components and materials. This offers a great opportunity for the innovation of China's automobile industry.

The strategic alliance for industrial technology innovation carries out active exploration and practical activities in a new cooperation mechanism of "demand oriented, joint investment, and achievement sharing." To promote collaborative research between enterprises and research institutes on critical generic technologies, the industry and university research cooperation mechanisms have been continuously reformed in recent years. For example, a number of collaborative innovation platforms have emerged with a view to promoting in-depth industrial cooperation. Through such innovation platforms, the alliance members have strived to make breakthroughs in a number of critical generic technologies. This has been under the support and guidance of government departments and based on the mechanism of "demand oriented, joint investment, and achievement sharing." This remarkably improves the degree of industrial collaboration and efficiency of collaborative innovation.

### 2.3 Innovation is increasingly active, and innovation ability and performance have improved steadily

All of the main automobile manufacturers in China have made progress in their R&D capabilities. Key automobile manufacturers (for example, Chongqing Changan Automobile Co., Ltd., SAIC Motor, Guangzhou Automobile Group Co., Ltd., Geely Holding Group, Great Wall Motor Co., Ltd., and BYD Co., Ltd.) have increased their R&D investments, built national enterprise technology centers, and integrated both domestic and international innovation resources. The intent is to strengthen their R&D ability and the technological competitiveness of their products. In recent years, the Chongqing Changan Automobile Co., Ltd. acquired R&D resources around the world including in Detroit, U.S., Birmingham, U.K., Turin, Italy, and Yokohama, Japan. This has effectively improved their R&D performance. Geely Holding Group increased its R&D investment substantially (the intensity of R&D investment was 3.5% in 2016), built a forward-looking global R&D center, and improved its R&D ability rapidly, while integrating and learning Volvo technologies.

Due to its long-term continuous R&D investment in new-energy automobiles and power batteries, BYD Co., Ltd. has acquired the core technologies of new-energy automobiles.

Critical component manufacturers have steadily strengthened their R&D abilities. In the field of critical components for new-energy automobiles, CATL and Jing-jin Electric have developed into automobile component manufacturers with international competitiveness. By the first half of 2017, CATL employed 3,628 R&D personnel, exceeding most automobile manufacturers. Its intensity of R&D investment reached 10.65%, far higher than the average level (2%) of China's automobile industry. Its intensity of R&D investment has reached the levels of the leading global automobile component manufacturers. In the field of components for conventional automobiles, Weichai Holding Group Co., Ltd., Wanxiang Group, Shengrui Transmission Co., Ltd., and Hangsheng Electronics Co., Ltd. have acquired innovation abilities and product competitiveness in certain subdivided fields. A number of leading Internet and communication enterprises (including Baidu, Ali Telecom, Tencent, Huawei, and ZTE) have successively entered the field of intelligently networked automobiles. As a result, this is gradually creating a firm basis for China to overtake the leading countries in the automobile components and aftermarket industries.

#### **2.4 The automobile industry innovation system has been preliminarily established, but some problems are yet to be solved**

At present, China's automobile industry has preliminarily established a technological innovation system that consists of enterprises, colleges, research institutes, social organizations, and government departments. However, the automobile power strategy is confronted with certain problems that need to be solved urgently. Among them, a primary problem is the lack of a non-profit applied technology research institute similar to Germany's Fraunhofer Society or the American national manufacturing innovation centers. These centers focus on the R&D of applied technologies at Levels 4 to 7 and can bridge fundamental research and technology industrialization.

First, strategic consultation for the automobile industry and technologies has not been researched sufficiently, and an all-round and systematic high-grade strategic consulting platform for the automobile industry does not exist. The automobile industry is characterized by high systematicness and long industrial chains. It also involves a wide range of sectors, overlapping management, and complex institutional mechanisms. China's automobile industry lacks a cross-sector and interdisciplinary high-class think tank platform that is oriented toward automobile power strategy and can provide consulting services for innovation strategies.

Second, the automobile industry innovation system is weak in internationalization ability, and the ability to utilize global

automobile innovation resources needs to be improved urgently. Compared with globally recognized automobile manufacturers, China's automobile manufacturers are still deficient in international development strategies, global R&D resource development and integration ability, and overseas project risk management. There is also a lack of global collaboration in innovation resources.

Third, the innovation chain is not complete, and a non-profit applied technology research institute that can bridge fundamental research with technology industrialization does not exist. Additionally, there is a lack of technology-based enterprises in China's automobile industry. This creates a distinct separation of automobile technologies and the economy. Fundamental research and original innovation are insufficient, and a non-profit applied technology research institute that can bridge fundamental research with technology industrialization is necessary. Without bridging university-dominated fundamental research with enterprise-dominated technology industrialization, no effective supply of applied technologies is available for the automobile industry.

Fourth, the existing innovation elements and platforms are confronted with problems of diversification in investment and deficiency in collaboration. In particular, strategic alignment and cooperation between industry and university level research and between different enterprises is insufficient. The total investment in technological innovation by the industry is insufficient, and this creates problems such as the diversification in investment, repeated investment, and inefficiency of R&D. Furthermore, in terms of collaborative innovation of the automobile industry, China lags behind the leading automobile producing countries.

### **3 Learning from overseas experiences**

#### **3.1 Experiences and models for the development of automobile industry innovation systems in foreign countries**

##### **3.1.1 Europe**

###### **(1) EUCAR**

In Europe, innovation has gone through three stages: 1) linear innovation; 2) system innovation; and 3) integrated innovation (also referred to as cluster innovation). The European automobile industry innovation system is dominated by EUCAR (a strategic consultative body for automobile technologies) and R&D promotion agencies for applied science (represented by the Fraunhofer Society).

Founded in 1994, EUCAR currently comprises Europe's 14 major automobile manufacturers and is committed to strengthening the competitiveness of Europe's automobile manufacturers through cooperative R&D and innovation. Specifically, EUCAR is committed to strengthening research into the strategic direction of R&D and innovation and communicating with the European Commission and its members about R&D projects. EUCAR specializes in the R&D of non-competitive technologies. By identifying the main challenges to automobile R&D, EUCAR

communicates with Europe's main stakeholders (including suppliers, academia, and research institutes), and initiates and supports related R&D projects. The achievements from these R&D projects are then applied to the automobile market within ten to twenty years.

#### (2) Germany's Fraunhofer Society

Founded in Munich on March 26, 1949, the Fraunhofer Society is the largest applied science research institute in Germany and Europe. To be specific, the Fraunhofer Society is a government-backed and market-oriented non-profit scientific research institute. It is committed to developing new technologies, products, and processes for enterprises (particularly medium and small-sized enterprises), and assisting enterprises to solve various problems encountered during their innovation activities. The Fraunhofer Society employs 24 000 scientific research personnel (including professors from German cooperating colleges and interning postgraduate students). Every year, the Fraunhofer Society provides services for more than 3 000 corporate customers and completes nearly 10 000 R&D projects.

In terms of management mechanisms, the headquarters of the Fraunhofer Society balances the distribution of benefits between the headquarters and affiliated research institutes by providing various professional services (for example, patent and contract review) for research institutes. In addition, the Fraunhofer Society demands that its research institutes prioritize public welfare to maintain Germany's national interests, maintain a positive reputation in the industry, and thus, win more market opportunities. This management mechanism leads to a balance between public welfare and profitability with applied technology services, and integration of non-profit research and market-oriented research. Ultimately, this stimulates innovativeness and ensures public welfare and technological spillovers affect of the R&D of applied technologies. It also effectively bridges fundamental research with technology industrialization and attains a genuine close connection between technologies and economic development.

The mission of the Fraunhofer Society is to provide scientific research services with a considerable product maturity (equivalent to the applied technologies with MRLs/TRLs 4 to 7 specified by the national manufacturing innovation centers in the U.S.). Through this, scientific and technological achievements can be quickly transformed into mature products in the market. In Germany, the Fraunhofer Society is well known as a sci-tech organization. The research institutes affiliated to the Fraunhofer Society are mainly engaged in bridging fundamental research by universities and prototype-oriented industrial R&D by enterprises. Their research attaches importance to the rapid transformation of industry and university level research, but also analyzes the development trends of different industrial sectors and strives to develop necessary cutting-edge technologies, thus creating a dynamic innovation impetus.

#### 3.1.2 The U.S.

The innovation system of the automobile industry in the U.S. experienced a transformation from a lack of government intervention to active guidance. Before the Second World War, the U.S. government did not intervene in scientific and technological research and delegated this to the market. To satisfy the needs of the war, the U.S. government became involved in scientific and technological research and formed the Office of Scientific Research and Development (OSRD). Subsequently, the President's Office of Science and Technology and the National Science and Technology Council (NSTC) were set up to coordinate scientific and technological innovation. In the 1990s, the U.S. government rendered further support for scientific and technological input across the U.S. and formulated a guiding plan for increasing R&D expenditure to 3% of annual GDP. They also encouraged the industry, academia, and diverse social forces to participate jointly in scientific and technological development.

The innovation system of the automobile industry in the U.S. comprises the strategic consultative body for automobile technologies (USCAR) and R&D promotion agencies for applied technologies. The latter is represented by the National Network for Manufacturing Innovation (NNMI). Specifically, the strategic consultative body for automobile technologies provides advice for the determination of the strategic orientation of automobile innovation and initiation of major projects. Subsequently, the R&D promotion agencies for applied technologies bridge the gap between fundamental research and industrialization.

In 1992, the three major automobile manufacturers in the U.S. (General Motors, Ford Motors, and Chrysler) jointly initiated and set up USCAR. USCAR is committed to strengthening technological cooperation between automobile manufacturers in the U.S. It is also an important communication platform for automobile manufacturers and governments, between research institutes and colleges, and between different energy enterprises. In conjunction with the U.S. government, USCAR has successively set up cooperative organizations, for example, the Partnership for a New Generation of Vehicles (PNGV), FreedomCAR, and U.S. DRIVE. This action plays an important role in improving the automobile fuel economy, promoting the development of hydrogen energy and fuel cells, and popularizing electric automobiles.

To revert to and revive the manufacturing industry, since 2012, and following the example of the Fraunhofer Society, a large number of innovation research institutes have been set up in the U.S. These research institutes are devoted to the R&D and promotion of applied sciences and create a pattern of cooperation between governments and the industry. In 2014, the U.S. released the NNMI program for the following purposes: 1) create a competitive, efficient, and sustainable innovation system that covers scientific research and manufacturing; 2) perfect the innovation ecosystem of the manufacturing industry in the U.S.; and

3) reduce the gap between R&D and applications and promote the transformation of R&D achievements.

Like the Fraunhofer Society, innovation research institutes in the U.S. are not involved in technologies that remain in the pure theory or engineering research stage. Rather, they concentrate on the technologies that are between the two stages and have just entered the prototype or small-batch market stage. As these technologies fail to reach the cost threshold in initial stages, manufacturing innovation is created to reduce their costs and improve their performance and reliability, thus transforming them into products or technologies that are more competitive. Innovation centers in the U.S. mainly focus on technologies with TRLs/MRLs 4 to 7. The research of these technologies is either fundamental research financed by public funds or R&D financed by private sectors.

Innovation centers in the U.S. have four remarkable characteristics. 1) They concentrate on material technologies and believe that materials are of vital importance in industrial value chains. The themes of multiple innovation centers are associated with materials. 2) They actively carry out cross-border integration. For example, the Composite Material Innovation Center integrates a variety of associated technologies (for example, material technology, simulation technology, OEM, testing technology, and molding technology). The center believes that innovation is more likely to occur in the cross-border areas. 3) Innovation systems in the U.S. are designed as a network, whose core strategy is to build an innovation ecosystem and accomplish the development of an entire industry. As a result, the innovation requirements are defined clearly, thus avoiding unnecessary waste in R&D, and various resources are shared (including laboratories, technological training, and technological information). 4) A leverage effect is achieved. The funds allocated to each innovation center are not sufficient. For example, the U.S. government and automobile industry jointly invested approximately 200 million dollars in an innovation center, but this investment can initiate a tenfold or larger industrial investment.

### 3.2 Learning: experiences and methods of developing innovation systems in foreign countries

With the development of innovation systems in foreign countries, the following summary can be used for reference.

First, it is necessary to strengthen the top-level design and strategic consulting ability. The more developed the automobile industry, the more important top-level design and strategic consultation become. The automobile industries of Germany and the U.S. are continuously innovative and stay ahead of other countries. Fundamentally, this is because the two countries have set up national strategic consultative bodies for automobile technology. They research the prospective and strategic issues relating to industrial development and provide strategic consultation and evaluation services for major decisions. They provide advice on

the determination of the strategic direction of automobile innovation in their home countries. They initiate major projects and build the chains between governments, enterprises, and research institutes necessary for the development of automobile technology. These strategic consultative bodies for automobile technologies are represented by EUCAR and USCAR.

Second, it is necessary to reform institutional mechanisms and build non-profit R&D promotion agencies for applied sciences. While building their innovation systems, Germany and the U.S. attached importance to top-level design and strategic consultation, and researched applied sciences. In response to the demands for innovation from the automobile industry, the Fraunhofer Society and the NNMI highlighted collaborative innovation and focused on the research of applied sciences and technologies. They also utilized existing innovation resources and carriers, assisted the industrialization of research achievements in applied sciences, and attempted to bridge fundamental research with technological industrialization.

## 4 Further suggestions

China's automobile industry needs to take the following actions to strengthen the automobile power strategy:

- 1) Actively implement the *Medium & Long-term Development Plan for the Automobile Industry*.
- 2) Emphasize the establishment of the China Automobile Innovation Council and the National Manufacturing Innovation Center for Automobile Industry.
- 3) Utilize existing innovation resources and newly built innovation entities.
- 4) Improve the strategic consulting ability for automobile technologies.
- 5) Strengthen networked and matrix-type collaborations.
- 6) Bridge the gap between fundamental research and industrial R&D.
- 7) Build a new-type innovation system for the automobile industry.
- 8) Integrate the industry chain, value chain, and innovation chain; and
- 9) Attempt to remain ahead in the innovation of the automobile industry.

### 4.1 Set up high-class think tanks, and strengthen the strategic consulting ability

Through the strategic consultative committee for the technology roadmap of energy-efficient and new-energy automobiles, China needs to establish the China Automobile Innovation Council. This can be achieved by pooling intellectual resources and technological pacesetters in automobile-related industries and university level research. The intent is to satisfy the strategic consultation needs of the automobile power strategy and build

a national strategic consultation and think tank platform for the innovation of the automobile industry. Overall, the China Automobile Innovation Council must become a strategic consultative body for the innovation of China's automobile industry. To build a high-end think tank for China's automobile industry, the council will comprise academicians, industry members, and industry experts.

The think tank will continuously analyze the technology roadmap for energy-efficient and new-energy automobiles. The think tank platform will provide high-class strategic consultation services in various aspects, for example, the development strategy of the automobile industry and the technology roadmap for energy-efficient and new-energy automobiles. They will also steer the orientation of national innovation projects initiated in the automobile field, and decision-making processes and dynamic evaluations of major projects. By combining international experience with China's specific conditions, the think tank platform will continuously conduct joint research and dynamic evaluations and hold professional seminars on energy-efficient and new-energy automobiles. Subsequently, it will take on a leading role in the innovational development of the automobile industry.

**4.2 Build networked and matrix-type innovation centers and increase the supply of applied technologies**

A National Innovation Center for Intelligent Networked Automobiles must be established. Based on the efforts of the Innovation Alliance for the Intelligent Networked Automobile Industry, it is necessary to set up the networked and substantiated National Innovation Center for Intelligent Networked Automobiles. This innovation center must identify the demand for generic technology and focus on applied technologies (equivalent to the applied technologies with TRLs/MRLs 4 to 7) in the stage of transformation from fundamental research to industrialization. It must also combine the experience of the Fraunhofer Society and the NNMI with China's specific conditions. In addition, a number of innovation sub-centers must be established through resource integration and combined with new constructions.

Backed by the innovation center network, innovation entities must strengthen the development of core technologies. Moreover, it is necessary to build national innovation platforms (for example, the National Innovation Center for Intelligent Networked Automobiles) and pool the preeminent innovation resources of the automobile industry. Additionally, the focus should be on the development of the core applied technologies that need to be industrialized (including power batteries, advanced automotive electronics, autopilot systems, core chips, and vehicle-mounted operating systems), and increase the supply of basic and generic technologies.

### **4.3 Carry out “one entity and two systems,” and increase the supply of applied technologies through diverse channels**

The state-owned Assets Supervision and Administration

Commission under the State Council is developing a classified reform and implementing the innovation-driving national strategy among the central enterprises. It is advisable to use this opportunity. The existing restructured research institutes should serve the automobile industry through hi-tech enterprise groups. Meanwhile, it is recommended to strip the industry-specific institutes that are engaged in the research of applied technologies and provide certain non-profit services. These research institutes must be appraised and managed with common standards for central enterprises or research institutes.

### **4.4 Build innovation resource sharing platforms, and improve the utilization efficiency of innovation resources**

In conjunction with the innovation entities (for example, key laboratories, engineering and technology research centers, colleges, research institutes, and social organizations) in the automobile field, it is necessary to promote the development of sharing platforms for innovation resources (for example, scientific research equipment, infrastructure, intellectual property, and innovative talents). Additionally, it is necessary to explore sharing, crowd-innovation, and crowdsourcing mechanisms, and improve the utilization efficiency of innovation resources.

### **4.5 Raise industrial investment funds, and promote the commercialization of key core technologies**

Guided by the related national industrial investment funds, it is necessary to attract the participation of various parties (for example, large enterprises, financial institutions, and social capitals) in the automobile industry and associated industries through a marketization mechanism. Industrial investment funds for energy-efficient and new-energy automobiles need to be established, and funds for the innovation and commercialization of key technologies in the fields of new-energy automobiles, intelligently networked automobiles, and energy-efficient automobiles must be allocated. Last, equal attention to venture investment and equity investment must be provided.

**4.6 Strengthen the sci-tech intermediary services, and improve the supporting serviceability for innovation**

Strategies for automobile-related human resources, standards, and patents must be formulated. It is necessary to build industrial support platforms on technical standards, tests and evaluations, infrastructure, and international cooperation. A suite of standards for complete automobiles and automobile components and a systematized serviceability in support of industrial development must be developed. It is necessary to improve the certification, inspection, and testability, create automobile development databases, engineering data centers, and patent databases. Additionally, it is necessary to provide sharing services for enterprises in respect to knowledge innovation and engineering data development.

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