IX. Engineering Management

1 Engineering research fronts

1.1 Development trends in the top 10 engineering research fronts

The fronts of global engineering management research focus on 10 topics: "service-oriented strategies of manufacturing enterprises," "charging strategies for electric vehicles," "utilization of land resources under the Shared Socioeconomic Pathway," "impact of climate change on water resources in arid regions," "diagnosis of mental diseases by using mobile-device sensors," "strategic plans for regional environmental management," "energy management based on distributed microgrid technology," "water–energy–food nexus," "application of ecosystem services in ecological risk assessment," and "influence of the built environment on commuting." The core papers on these topics are summarized in Tables 1.1.1 and 1.1.2. Front studies on these topics have been published in the fields of mechanical engineering, electrical engineering, energy, environment, medical science, construction, agriculture, and other disciplines, while key interpretations for the topics of "service-oriented strategies of manufacturing enterprises," "charging strategies for electric vehicles," and "utilization of land resources under the Shared Socioeconomic Pathway" have been obtained. The current and future development trends of these studies are discussed further in the later sections of this work.

(1) Service-oriented strategies of manufacturing enterprises

With the development of the economy, most customers are no longer satisfied with merely purchasing goods and have started demanding services to accompany these goods. Therefore, enterprises have begun to offer their customers goods–services packages to meet their expectations and satisfy their needs, while an increasing number of traditional enterprises have begun shifting their focus from goods to services. By providing more value-added

Table 1.1.1 Top 10 engineering research fronts in engineering management

No.	Engineering research front	Core papers	Citations	Citations per paper	Mean year	Percentage of consistently-cited papers	Patent-cited papers
1	Service-oriented strategies of manufacturing enterprises	13	288	22.15	2015.92	23.1%	0.00
2	Charging strategies for electric vehicles	18	406	22.56	2015.50	0.0%	0.00
3	Utilization of land resources under the Shared Socioeconomic Pathway	13	381	29.31	2015.54	7.7%	0.00
4	Impact of climate change on water resources in arid regions	4	206	51.50	2016.25	25.0%	0.00
5	Diagnosis of mental diseases by using mobile-device sensors	5	172	34.40	2015.40	20.0%	0.00
6	Strategic plans for regional environmental management	4	51	12.75	2016.75	0.0%	0.00
7	Energy management based on distributed microgrid technology	4	42	10.50	2016.75	50.0%	0.00
8	Water–energy–food nexus	5	57	11.40	2016.40	0.0%	0.00
9	Application of ecosystem services in ecological risk assessment	4	38	9.50	2016.75	0.0%	0.00
10	Impact of built environment on commuting	4	64	16.00	2016.25	0.0%	0.00

Table 1.1.2 Annual number of core papers published for the top 10 engineering research fronts in engineering management

No.	Engineering research front	2012	2013	2014	2015	2016	2017
1	Service-oriented strategies of manufacturing enterprises	0	1	1	3	1	7
2	Charging strategies for electric vehicles	0	0	2	8	5	3
3	Utilization of land resources under the Shared Socioeconomic Pathway	2	0	3	0	0	8
4	Impact of climate change on water resources in arid regions	0	0	0	0	3	1
5	Diagnosis of mental diseases by using mobile-device sensors	0	0	0	3	2	0
6	Strategic plans for regional environmental management	0	0	0	0	1	3
7	Energy management based on distributed microgrid technology	0	0	0	0	1	3
8	Water–energy–food nexus	0	0	0	0	3	2
9	Application of ecosystem services in ecological risk assessment	0	0	0	0	1	3
10	Impact of built environment on commuting	0	0	1	0	0	3

services, manufacturing enterprises have switched from product homogenization to service differentiation and from selling a single product to providing overall solutions to the needs of their customers. Manufacturing servitization is an advanced manufacturing mode that combines manufacturing with service and ensures a coordinated development of manufacturing services and service-oriented manufacturing. The key issues in manufacturing service research include the influence mechanism of the manufacturing servitization business model, product and service optimization matching and design, manufacturing- and service-integrated optimization decision control, collaborative management of the product servitization supply chain, and the role of new information technologies in servitization transformation.

(2) Charging strategies for electric vehicles

With the tight supply-and-demand relationship of petroleum resources around the world and the increasingly strict regulations on vehicle emissions, new energy vehicles, typified by electric vehicles, represent an important development trend in the automobile industry. To reduce the energy consumption of charging vehicles and to improve the security of power grids, several countries have adopted the electric-vehicle charging strategy as a strategic research direction. Electric vehicles are electric loads for which practical use is being hindered by two key problems. First, the current energy supply methods for electric vehicles include slow charging, fast charging, and battery replacement, while their power consumption during driving is affected by various factors, including unit mileage power consumption, load capacity, and road conditions. Therefore, a reasonable charging method must be determined to minimize the costs of charging and to promote the development of electric vehicles while taking their charging requirements into account. Second, the disorderly charging of electric vehicles can produce harmful effects, such as increasing the peak–valley difference in power systems and voltage drops in local areas. The orderly charging of electric vehicles is among the most convenient and feasible ways to realize the peak load shifting of power systems and improve the economic operation of electric vehicles.

(3) Utilization of land resources under the Shared Socioeconomic Pathway

Shared Socioeconomic Pathway (SSP) is a new framework in land utilization, ecological environment, and climate change research. SSP predicts future development trends, reveals the logic of causal relationships, and shows historical trends that cannot be easily captured by using models. This framework also supplements the predictions of quantitative models, which quantify the basis and meaning of SSP predictions (e.g., future changes in population, human development, economy, lifestyle, policies, institutions, technologies, environments, and natural resources) based on several key qualitative description factors. SSP has been divided into five paths—sustainable development, regional competition, inequality, fossil fuel development, and intermediate development—all of which aim to address the challenges related to climate change alleviation and adaptation, ensure future social and economic development, and facilitate climate change research and policy analysis. The utilization of land resources under SSP fully covers all potential development situations, satisfies the demands of agricultural and industrial development, provides guidance for various laws and regulations, and requires improvements in the position, productivity, environmental influence, trade, and globalization of future markets. By using data on land utilization changes and classifying aerial scenario images, this research front focuses on developing energy, agricultural, and production systems, reducing greenhouse gas (GHG) emissions and environmental influences, alleviating the harmful effects of climate change and urbanization, providing solutions to climate policy and other social objectives, and improving biodiversity conservation, ecosystem service value, and land utilization sustainability.

(4) Impact of climate change on water resources in arid regions

Climate change can transform the spatial distribution and temporal variation characteristics of atmospheric precipitation, thereby altering water circulation systems and influencing the spatiotemporal pattern of water resources. Under the joint influence of social economy development and global climate change, the demand for water resources in arid regions is gradually increasing along with the increasingly harmful effects of drought. Studies on the influence of climate change on water resources in arid regions have mainly focused on the ocean–atmosphere–land interface, water resources and ecological impacts in arid regions, the simulation and evaluation of the effects of global and regional climate modes on the climate in arid regions, the prediction of the spatiotemporal patterns of water resources in arid regions across various climate change situations by using hydrological models, the uncertainty of the influences and predictions of the climate mode and assessment models, and the use of technologies to monitor and forecast drought hazards and issue alerts. Conducting quantitative research on the spatiotemporal response features of water resources in arid regions, especially the frequency, cycle, strength, duration, and influence of extreme hydrological processes, under the background of climate change is of great importance in preventing and mitigating extreme hydrological disasters, maintaining social stability, and ensuring sustainable economic development.

(5) Diagnosis of mental diseases by using mobile-device sensors

Sensors receive relevant signals or stimuli and produce the necessary responses. These devices can also send physical or chemical quantities to be measured to another device in a specific time and space to meet the requirements of information transmission, storage, and processing. Mobile devices, such as smartphones, computers, and wearable sensors, can continuously monitor behavioral components (e.g., decreased activity, delayed mental activity, and changes in sleeping patterns) and motivational states (e.g., loss of pleasure) associated with mental diseases as well as the physiological states (e.g., heart rate, body temperature, and skin electrical reactions) of people with mental diseases. These data can help psychiatrists conduct real-time monitoring, provide their patients with behavioral intervention, and control their conditions. Mobile-device sensors are widely used as advanced technologies for diagnosing mental diseases. However, some challenges hinder their application, particularly their inability to connect the vast amount of data to the feelings of patients. Moreover, one cannot guarantee that patients will strictly follow their treatment process. As an application prospect, mobile-device sensors can encourage healthy behaviors of individuals by using the Internet of things and subsequently improve their mental health. However, the use of mobile-device sensors for mental disease diagnosis and intervention is still in its infancy. Nevertheless, a new generation of technologies is expected to bring revolutionary changes in digital psychiatry practice and support the global population.

(6) Strategic plans for regional environmental management

As economic development is gradually regionalized, the regionalization of environment problems is becoming increasingly apparent. Unlike the traditional environmental treatment mode that focuses on the companies or projects of the point source, the regional environmental treatment mode that uses the entire natural region as its treatment object has become increasingly important. Regional environmental treatment plans must regard those ecological regions that are divided by natural boundaries as their treatment objects, and environmental actors in ecological regions (especially local governments) must serve the overall environmental interests of their respective regions. Area division and cooperative treatment are basic features of regional environmental treatment plans. The special nature of environmental problems requires the implementation of unique treatments in different areas based on the characteristics of their natural regions. All administrative regions in a natural ecological area must cooperate in implementing environmental treatments to achieve their environmental objectives. Extant studies on regional environmental treatment plans have mainly focused on ecological civilization, air pollution, and haze treatment. The key issues in this front include the legal protection and accountability mechanism of regional environmental treatment and the roles of local government cooperation and composite incentive mechanism construction in cross-regional environmental treatment. Investigating the multiple collaborative management mode, division of responsibilities, and legal protection of local governments in natural regions under the background of regional environmental treatment are of great importance in enhancing cooperation among local governments and preventing and mitigating environmental pollution problems in a region.

(7) Energy management based on distributed microgrid technology

A distributed microgrid is a small power distribution system with distributed power sources, energy storage and conversion devices, related loads and monitoring tools, and protection devices. The most prominent difference between a microgrid and a conventional distribution and power supply network is that the former can operate independently while ensuring power quality. A microgrid also combines modern technologies, such as energy conversion tools, power electronics, power grids, and automatic controls, and presents an important direction for the future development of energy technologies. The development of energy management technologies based on distributed microgrid technology can motivate further studies on control strategies; lead to the formulation of punitive solutions for the abandonment of excess heat generation; and increase the flexibility, accessibility, reliability, and cost-effectiveness of grids. Instead of merely selling electricity, enterprises can integrate the four functions of power generation, power distribution, power management, and electricity sales and realize flexible microgrid control through efficient distributed energy integration, which in turn can support the development of new supply modes. Hot research topics in this area include using a distributed microgrid to integrate renewable energy, energy storage systems, and local loads into the grid optimization configuration; using a microgrid to exceed the new energy penetration power limit; paralleling multiple microgrids; stabilizing microgrids in grid-connected and island operations; using microgrids to improve power quality; applying stochastic energy management to solve issues related to uncertain random supply and demand and to improve the balance of supply and demand in the whole system; improving power quality, energy utilization, autonomy, and adaptability; using a multi-micro network coordinated control strategy to improve the stability of the multi-micro network; developing an energy management system with prominent interaction functions; solving the optimization strategy based on the time–demand response; developing new power electronic equipment (e.g., grid-connected inverters, static switches, and power control devices) as supporting equipment; and developing superconductor energy storage technologies for microgrids and super capacitors.

(8) Water–energy–food nexus

The water–energy–food nexus implies a close relationship among water safety, energy safety, and food safety. The operation, decision, and movement of any of these resource systems are related to changes in the other two systems. However, the coping strategies of a resource system always lead to the transfer of problems from one resource system to another, thereby creating a dilemma in resource treatment. This nexus necessitates a shift from pursuing the efficiency of a single department to exploring cohesive and comprehensive solutions to resource problems from cross-departmental perspectives. However, this shift can introduce fundamental changes in resource governance concepts and challenge the current structure, policy, and procedure at the global, regional, and (sub)state levels. The water–energy–food nexus has three core aspects: the interactional core nexus of water, energy, and food in production, consumption, and waste treatment processes; the internal influential relationships formed by population, trade, and climate change elements; and the external influential relationships formed by the impact of nexus changes on the social–economic–ecological system. The number of studies on this nexus is rapidly increasing at the global, domain, and family levels, while data are being collected at the urban and regional levels to develop the necessary research tools. Along with the standardization of criteria for data calculation—the integration of the WEF-Nexus model in all spatiotemporal dimensions, the monitoring of data, the supply and demand of multiple resources, the development of integrated models for the toughness and sustainability of the infrastructure (green, gray, and blue) system, and the creation of an intelligent decision system—the WEF-Nexus paradigm is expected to become an important tool for ensuring the sustainable development of human society.

(9) Application of ecosystem services in ecological risk assessment

Ecosystem services (ESs) refer to life support products and services that are directly or indirectly obtained by humans through the structure, processes, and functions of ecosystems. These services include supply, regulatory, cultural, and support services, the sustainable supply of which provides a foundation for ensuring sustainable economic and social development and directly benefits humans. ESs clarify the link between human well-being and ecosystem structures and processes. They have been applied in ecological risk assessment to define the environmental value that must be maintained; to analyze the risks in the structure, process, and function of an ecosystem subjected to external pressures; to examine the complex processes of an ecosystem; to consider the integrality and complexity of an ecosystem in the risk analysis process; to assess the impact of service output based on a holistic characterization of ecological risk; to examine how highly comprehensive environmental protection, environmental policymaking, and other policy and implementation actions can be promoted; to investigate the comprehensive action policy of environmental quality standards; and to assess the risks to human health and ecology. In the ecosystem process and service discipline, ESs mainly focus on the classification and tradeoff of ecosystem services; the formation and provision of mechanisms, quantitative analysis, and evaluation methods; the scale effect and regional integration; and the optimal regulation of ecosystem services. The key issues in the application of ESs in ecological risk assessment include comprehensively evaluating the direct or indirect interactions among various risk sources and receptors in ecosystems, establishing a system for simulating and evaluating ecological risk in ecosystems, using the ecological production function to assess the influence of an external pressure disturbance on the ecosystem service output and to measure the resulting risk of applying external pressure on the system material energy flow and circulation rate, examining the causal relationship between the ecological system process and the social economy, establishing a nonlinear risk assessment model for subsystems, improving the docking between the evaluation process and the social ecological management process, promoting research on ecosystem services in the follow-up stage of ecological risk assessment, and integrating the game strategies of various stakeholders into the evaluation process.

(10) Impact of built environment on commuting

Aside from traffic congestion charges, odd–even traffic schemes, fuel taxes, and other travel-demand-management strategies, emphasizing the positive effect of the built environment on traffic and reducing the dependence of people on vehicles are essential in solving traffic problems. The formation of a built environment has a deep-rooted influence on the daily travel behavior of commuters, which in turn determines the spatial distribution of urban residents' activities at the macroscopic level. This distribution cannot be easily changed after the formation of an urban built environment and may produce a long “lock-in effect” on traffic. Given that commuting is an important daily activity, how to optimize the urban built environment to affect the commuting demand, reduce car ownership and use, and encourage people to engage in green travel to alleviate traffic problems have become hot research topics in urban traffic planning and related disciplines. The development of big data and spatiotemporal behavioral science in recent years provides a feasible means of collecting data on the relationship between the built environment and commuting. The key issues in this area include examining the micro-mechanism of the influence of the multi-scale built environment on commuting, testing the synergistic effect of the built environment and traffic demand management on commuting, investigating the influence mechanism of the built environment on multidimensional traffic behavior, and studying the correlation mechanism between the built environment and rail commuting. In the context of China's urban development, examining how the built environment of typical Chinese cities affects commuting can provide a theoretical basis and decision-making support for the formulation of land use, traffic planning, and traffic-demand-management strategies in China.

1.2 Interpretations for three key engineering research fronts

1.2.1 Service-oriented strategies of manufacturing enterprises

The concept of manufacturing servitization was introduced by Vandermerwe and Rada in 1988, and it was later defined by Needly from Cambridge University, as the innovation of organizational capabilities and processes that create value for customers and businesses from the sale of products to the provision of products and related services. In other words, manufacturing servitization is essentially a process of transforming product service systems. Strategically, this process can enhance the relationships of enterprises with their customers and contribute to their sustainable development. Economically, services have a high profit margin as well as a long-lasting and stable revenue stream. Environmentally, the full life-cycle management of products implemented by manufacturing enterprises under servitization can reduce the consumption of resources. The "Made in China 2025" initiative highlights a productive service industry as an important source of support for transforming and upgrading the manufacturing industry and presents the only way to upgrade the industrial value chain.

Manufacturing servitization can be divided into three main modes. Take the case of Philips as an example. The company sells nuclear magnetic resonance equipment to medical institutions in the mode of manufacturing servitization and provides maintenance and repair services in the mode of equipment use. In the use-oriented mode, when renting out equipment to medical institutions, Philips charges a rental fee depending on the time of use. Meanwhile, in the results-oriented mode, Philips directly provides inspection services and conducts a final inspection of the diagnostic results.

Early studies on manufacturing servitization are mainly concentrated in Europe, and this topic was not examined in China until around 2008. Service-oriented manufacturing is a service transformation business model adopted by manufacturing enterprises. Chinese scholars specializing in manufacturing servitization mainly come from Shanghai Jiao Tong University and Xi'an Jiao Tong University, of which the former has recently completed a National Natural Science Foundation project on China's service-oriented manufacturing in 2013. Despite the large number of studies that guide the practice of enterprises, all of them are placed at the forefront of the world.

Four hotspots in manufacturing servitization research, namely, competitiveness of manufacturing service business models, configuration of the product service system, control and collaboration in manufacturing and services, and manufacturing servitization based on new information technology, are discussed in detail in the following sections.

(1) Competitiveness of manufacturing servitization business models. The advantages of the manufacturing service business model have been widely recognized in academic and business circles. Although many well-known manufacturers, such as IBM, Royce, and Shaanxi Drum, have successfully transformed their business models, other enterprises, such as Intel, have lost profits during their transition and have even completely abandoned their adoption of this model. This situation has been referred to by academic circles as the "paradox of servitization." Research on the competitiveness of the manufacturing service business model has theoretical significance for enterprises and guides their selection of suitable service modes. Hot topics in this area include the choice of service type, the choice of breadth of service, the configuration of products, and the influence of service investments, the market competition environment, and product and industry characteristics on service performance.

(2) Product service system configuration. A product service system refers to the product service package provided by manufacturing servitization enterprises that emphasizes the integration of products and services, even the whole solution, to achieve a 1 + 1 > 2 integration effect. The configuration of a product service system begins from understanding the requirements of consumers, translating such requirements to product and service feature requirements, and optimizing the configuration via knowledge engineering or by using an optimization model. Given the continuous development of new information technologies, the product service configuration must focus on the whole product or service life cycle; fuse and seamlessly integrate products, services, and information based on the demand of users; and integrate products, services, and information into business models. Meanwhile, the hot topics in the product service system and product and service optimal configuration include the choice of product service system mode, the optimized configuration of the product service system, and the personalized customization of the product service system.

(3) Control and collaboration in manufacturing and services. By integrating manufacturing and services, service-oriented manufacturing must also integrate and optimize various manufacturing and service processes, combine manufacturing and service capabilities, and develop a complete system

function to achieve an overall system optimization. However, given the involvement of customers in the process, manufacturing and service integration control must also consider the behavior of these customers. The product and service flows can also affect and interact with each other and must be managed collaboratively. The rapid development of information technology can help manufacturing companies achieve integrated control and collaborative management of manufacturing and services. Hot topics related to this area include joint forecast of product and service demand, optimal configuration and real-time allocation of manufacturing and service hybrid system resources, optimization of the manufacturing and service integration control system under new information technology, and development of a coordinating mechanism for product manufacturers and service providers.

(4) Manufacturing servitization based on new information technology. A new generation of information technology, represented by big data, cloud computing, and the Internet of things, has not only enhanced the function and effectiveness of product services but also created added value by providing services based on new information technology and introducing a new mode of service operation. Therefore, examining the service mode and its selection under the background of new information technology is important in promoting the shift of enterprises to intellectualization and servitization, enhancing the integration of products and services, and increasing the competitiveness of the enterprise market. Hot topics related to this area include using new information and communication technology to realize the fusion of products and services, launching a new service form under the background of information and communication technology, examining the value creation mode of manufacturing enterprises, and investigating the service transformation of manufacturing enterprises under the background of information and communication technology.

Given its rapid development, the impact of new information technology on the services of manufacturing enterprises has become a research hotspot. Extant studies have mainly examined the mechanism of new information technology in promoting servitization and the role of such technology in servitization transformation. These studies also have emphasized the need to consider the behavior and demand of customers to improve product design, manufacturing processes, and service integration optimization theory. The product servitization supply chain must coordinate the manufacturing, maintenance, spare parts supply, and logistics systems, and achieve supply chain coordination under a use/results-oriented product service system. Interdisciplinary studies in computer science, operational research, management science, engineering, and other disciplines must be strengthened in the future. From the application perspective, China has demonstrated promising performance in promoting service-oriented manufacturing in the large aircraft, high-speed rail, shipbuilding, nuclear power, and other high-end equipment manufacturing industries.

Finland, UK, and the USA are the top three countries that have published the largest number of core papers related to the service-oriented strategy of manufacturing enterprises (Table 1.2.1), while New Zealand, Canada, and Switzerland are the top three countries with the largest average number of citations (Table 1.2.1). Among the top 10 countries/regions that have published the largest number of core papers, UK, Spain, Finland, Sweden, and Switzerland have demonstrated the largest degree of cooperation (Figure 1.2.1).

Linkoping University, Aalto University, and the University of Cambridge are the top three institutions that have published the largest number of core papers (Table 1.2.2). Meanwhile, Boston University, Dartmouth College, and MIT have shown the largest degree of cooperation among the top 10 universities that have published the largest number of core papers (Figure 1.2.2).

Table 1.2.3 shows that the number of citing papers of China has not yet entered the ranks of the top ten. So it means that China is in a non-following position on service-oriented strategy research of manufacturing enterprises.

1.2.2 Charging strategies for electric vehicles

With a tight supply–demand relationship for fossil fuels globally, new energy vehicles, such as electric vehicles, represent an important development trend in the automobile industry. Electric vehicles have unique advantages over traditional fuel vehicles, including no pollution, low noise, high energy efficiency, and easy maintenance, all of which have prompted many countries to increase their production of electric vehicles. For instance, in 2017, China sold approximately 777 000 electric vehicles, which was 53.3%

Table 1.2.1 Countries or regions with the greatest output of core papers on the "service-oriented strategies of manufacturing enterprises"

No.	Country/Region	Core papers	Percentage of core papers	Citations	Percentage of citations	Citations per paper
1	Finland	5	38.46%	100	34.72%	20.00
2	UK	5	38.46%	59	20.49%	11.80
3	USA	4	30.77%	116	40.28%	29.00
4	Switzerland	3	23.08%	110	38.19%	36.67
5	Sweden	3	23.08%	70	24.31%	23.33
6	Spain	3	23.08%	32	11.11%	10.67
7	Italy	2	15.38%	12	4.17%	6.00
8	Canada	1	7.69%	45	15.63%	45.00
9	New Zealand	1	7.69%	55	19.10%	55.00
10	Ireland	1	7.69%	20	6.94%	20.00

Table 1.2.2 Institutions with the greatest output of core papers on the "service-oriented strategies of manufacturing enterprises"

No.	Institution	Core papers	Percentage of core papers	Citations	Percentage of citations	Citations per paper
1	Linkoping University	3	23.08%	70	24.31%	23.33
2	Aalto University	3	23.08%	35	12.15%	11.67
3	University of Cambridge	3	23.08%	47	16.32%	15.67
4	Boston University	2	15.38%	102	35.42%	51.00
5	Dartmouth College	2	15.38%	102	35.42%	51.00
6	MIT	2	15.38%	102	35.42%	51.00
7	Hanken School of Economics	2	15.38%	65	22.57%	32.50
8	University of Granada	2	15.38%	12	4.17%	6.00
9	HEC Montreal	1	7.69%	45	15.63%	45.00
10	IMD International	1	7.69%	45	15.63%	45.00

Table 1.2.3 Countries or regions with the greatest output of citing papers on the "service-oriented strategies of manufacturing enterprises"

No.	Country/Region	Citing papers	Percentage of citing papers	Mean year
1	UK	39	20.31%	2016.59
2	USA	28	14.58%	2016.04
3	Finland	27	14.06%	2016.52
4	Sweden	21	10.94%	2016.57
5	Germany	20	10.42%	2016.70
6	Italy	19	9.90%	2016.63
7	Spain	14	7.29%	2016.50
8	Switzerland	10	5.21%	2016.30
9	Denmark	7	3.65%	2016.86
10	Australia	7	3.65%	2016.86

Figure 1.2.1 Collaboration network among major countries or regions in the engineering research front of "service-oriented strategies of manufacturing enterprises"

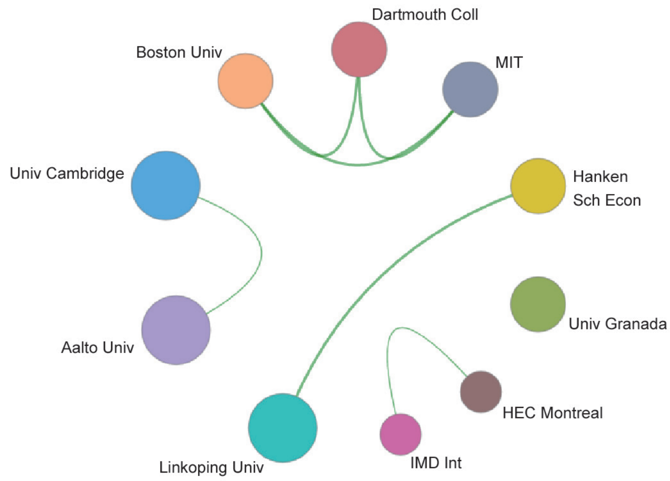

Figure 1.2.2 Collaboration network among major institutions in the engineering research front of "service-oriented strategies of manufacturing enterprises"

higher than the electrical vehicle sales in the previous year. However, given the restricted amount of electricity stored in their batteries, electric vehicles have limited mileage, which prevents the market share of electric-vehicle manufacturers from increasing further. Moreover, the charging demand of electric vehicles shows great randomness as reflected in their diverse charging methods and complex charging site selection. Therefore, a scientific electric-vehicle charging strategy must be developed to promote the large-scale production of electric vehicles.

(1) Optimal selection of charging mode. Electric vehicles have three charging modes. First, the slow-charging mode can effectively extend the service life of batteries. This involves charging electric vehicles during off-peak hours and discharging them during peak hours, thereby reducing their charging cost and increasing their discharge revenue. However, this mode requires a long charging time and cannot meet the charging demand of vehicles during driving. Second, the fast-charging mode requires a short charging time and can charge or discharge vehicles in large capacities. However, apart from the low charging efficiency and high charging cost of this mode, the large current generated during the charging process can reduce the battery life and affect the quality of the power system. Third, the battery replacement mode has a short changing time, thereby providing convenience to users of electric vehicles. However, the battery shape of these vehicles and their other parameters cannot be easily standardized within a short period, and the high cost of supporting infrastructure restricts the promotion and application of this mode. Therefore, to minimize charging costs and determine the shortest driving route, a charging-mode selection model for electric vehicles was built while taking the constraints of battery capacity, charging time, power distribution system node voltage, power system trends, and user satisfaction into account. The fast-charging, slow-charging, or battery replacement modes were optimized for various scenarios according to the goals and preferences of users.

(2) Electric-vehicle path selection and charging navigation optimization arrangement. When the traffic condition information is determined in advance, a multi-objective decision model with the shortest travel time and lowest charging cost under various electricity price mechanisms was constructed while considering the constraints of path selection and battery capacity as well as the mutual exclusion of charge and discharge states. Different electricity prices were set according to the operating conditions of the grid load at peak to achieve an orderly charge, shift the peak load, and improve the security of the power grid.

(3) Electric-vehicle path optimization and charging navigation based on crowd sensing. When the traffic condition information is known to be uncertain in advance, the user can actively upload the perceived real-time traffic condition and charging reservation information to the decision center (cloud platform) by using mobile smart devices, such as GPS-

equipped mobile phones, during their travel. The use of infrared sensors installed in charging stations and chargers enables the number of electric vehicles waiting to be charged and being charged to be confirmed, and real-time information on traffic rate and charging stations can be obtained. A path optimization and charging navigation decision model with the optimal path, charging station waiting time, electric-vehicle battery loss, and charging costs was constructed while considering the constraints of path selection, driving time, battery capacity, and power distribution system node voltage. Guiding the user to orderly charge and discharge can alleviate the harmful effects of the access to a large number of electric vehicles on the operation of the power system.

Many scholars have recently aimed to improve the charging strategies for electric vehicles. For instance, in 2016, Turkish scholars Bunyamin Yagcitekina and Mehmet Uzunoglu proposed a two-layer intelligent charging strategy for electric vehicles that uses the electric-vehicle smart charging management algorithm to achieve two-level control and to determine the optimal charging path of electric vehicles, thereby reducing the charging cost. The transformer capacity, state of the charging station, and shortest route to the charging station were all considered before using the first level of control to charge the vehicles. The second level of control was used in the process of charging electric vehicles to ensure stable and safe charging, to reduce the negative impact of the charging process on the power grid, and to prevent the transformer from overloading. In 2017, South Korean scholars Sang Keun Moon and Jin Kim proposed a charging demand management method for electric vehicles. By constructing a curve for the influence of electricity price fluctuations on fluctuations in charging demand, they aimed to find the balance point between user charging cost and electric load to reach the ideal state and successfully reduced the number of charging operations. In 2016, American scholars Mostafa Majidpour, Charlie Qiu, and others conducted predictive research on electric-vehicle charging load by conducting site measurements or collecting customer charging and site record data from the charging station exit port. By using four different prediction algorithms, including the weighting algorithm based on adjacent time points, time series prediction algorithm, support vector regression algorithm, and random forest algorithm, they found that using electric-vehicle user data can effectively improve the accuracy of charging load forecasting; however, it increases the risk of leaking the private information of electric-vehicle users. The number of studies on charging strategies for electric vehicles is continuing to increase along with the number of these vehicles, their types of users, and their driving coverage. For example, some studies have begun to examine the optimization of electric-vehicle driving paths, the selection of charging modes, and the planning of charging infrastructure to coordinate the operations of power and transportation systems and improve their operation efficiency.

China, the USA, and Germany are the three countries that have published the largest number of core papers related to charging strategies for electric vehicles (Table 1.2.4). Meanwhile, Belgium, Germany, and the USA are the three countries that have published the most frequently cited papers on this topic (Table 1.2.4). Figure 1.2.3 shows a high degree of cooperation between China and the USA among those countries that have produced core papers on this topic.

Cardiff University, the University of Hong Kong, and the University of Würzburg are ranked as the three institutions that have published the largest number of core papers related to charging strategies for electric vehicles (Table 1.2.5). Figure 1.2.4 shows strong cooperation between Cardiff University and Tianjin University.

From 2012 to 2017, China published six core papers on charging strategies for electric vehicles (Table 1.2.4). These papers were mainly written by researchers from the University of Hong Kong, Tianjin University, and Hunan University (Table 1.2.5).

1.2.3 Utilization of land resources under SSP

The land system faces many challenges from all aspects, such as satisfying the demand of human beings for food, protecting landscape functions, maintaining and improving the ecosystem service value, and alleviating climate change. Given that the driving factors of land utilization (e.g. population, economy, technology, policy, and soil) have great associated uncertainties, the dynamic change trends of land utilization cannot be easily imitated by using the traditional mode. Under SSP, studies on land resource utilization can analyze the dynamic changes of land under various paths by considering several influential factors. Some research achievements have been realized in the areas of energy utilization, environmental protection, and urbanization, but further research must be

Table 1.2.4 Countries or regions with the greatest output of core papers on the “charging strategies for electric vehicles”

No.	Country/Region	Core papers	Percentage of core papers	Citations	Percentage of citations	Citations per paper
1	China	6	33.33%	153	37.68%	25.50
2	USA	4	22.22%	109	26.85%	27.25
3	Germany	4	22.22%	115	28.33%	28.75
4	UK	4	22.22%	62	15.27%	15.50
5	Croatia	1	5.56%	27	6.65%	27.00
6	Switzerland	1	5.56%	27	6.65%	27.00
7	Belgium	1	5.56%	31	7.64%	31.00
8	Italy	1	5.56%	24	5.91%	24.00
9	Australia	1	5.56%	13	3.20%	13.00
10	Bosnia & Herceg	1	5.56%	16	3.94%	16.00

Table 1.2.5 Institutions with the greatest output of core papers on the “charging strategies for electric vehicles”

No.	Institution	Core papers	Percentage of core papers	Citations	Percentage of citations	Citations per paper
1	Cardiff University	3	16.67%	39	9.61%	13.00
2	University of Hong Kong	2	11.11%	73	17.98%	36.50
3	University of Würzburg	2	11.11%	61	15.02%	30.50
4	Tianjin University	2	11.11%	24	5.91%	12.00
5	Argonne National Laboratory	1	5.56%	40	9.85%	40.00
6	Hunan University	1	5.56%	40	9.85%	40.00
7	FZI Research Center for Information Technology	1	5.56%	34	8.37%	34.00
8	University of Zagreb	1	5.56%	27	6.65%	27.00
9	China Electric Power Research Institute	1	5.56%	18	4.43%	18.00
10	Tianjin Electric Power Research Institute	1	5.56%	6	1.48%	6.00

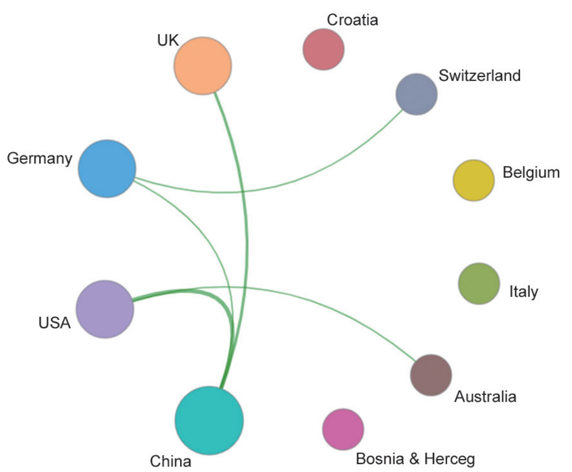

Figure 1.2.3 Collaboration network among major countries or regions in the engineering research front of “charging strategies for electric vehicles”

conducted on the theoretical and actual application of SSP as soon as possible. Specifically, future studies on SSP must focus on the following.

(1) Influence of land resource utilization on environmental protection. Land utilization and the related changes directly affect biodiversity conservation, GHG emission, soil quality, and food production. The carbon emissions generated by the transformation of agricultural land to forest land have been identified as an important driver of global warming. Problems in improving agricultural productivity must be solved as soon as possible to facilitate the expansion of agricultural land. The global land utilization mode, MAgPIE (regarding the influence of agricultural production mode on the environment), is an important tool for evaluating the economic

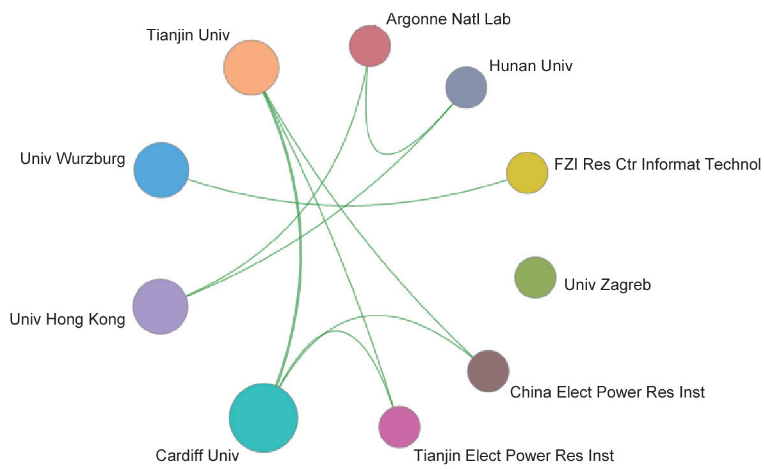

Figure 1.2.4 Collaboration network among major institutions in the engineering research front of "charging strategies for electric vehicles"

and environmental influences of land utilization. Under different SSP conditions, waste and GHG emissions produce different effects on landscape changes and ecosystem service value, thereby proving that laws and regulations, protection of natural forests, development and improvement of the carbon sink, and utilization of low-carbon technology are essential measures for environmental protection.

(2) Influence of land resource utilization on energy utilization. Energy plays an important role in satisfying the basic demands for human development and well-being. Future changes in the demand of humans for energy reserves and the demand characteristics are fundamentally influenced by social and economic conditions, availability of energy and resources, energy supply, transformation technology, and ultimate usage of energy. Meanwhile, GHG emissions and other environmental and external social factors can influence energy supply and demand. Therefore, the development of an energy system is influenced by the changes in social demands and the choice of strategic policy. Global land utilization and global energy–economy–climate models are important tools in energy utilization research.

(3) Influence of land resources utilization on urbanization. A study on metropolitan suburbs revealed that nonagricultural land expansion is mainly characterized by an increase in industrial land, which subsequently leads to an increase in farmland and a reduction in woodland. A country-initiated increase in farmland leads the expansion of nonagricultural land, while all the other developments from lower levels are of little significance. This observation may be partially explained by the fact that, while adapting to the increasing demands of the population and the effects of economic growth, the plan plays a key role in improving spatial growth and attracting external investments. Rapid urbanization in China is occurring along with farmer immigration and changes in farmland utilization strength. The relationship between farmer immigration and farmland utilization strength remains unclear, although previous studies have shown that farmer immigration has an opposite P relationship with farmland utilization strength. The positive influence of productivity increase caused by the household responsibility system is identified as the primary driver of the increase in farmland utilization strength. Meanwhile, the labor shortage resulting from the excessive loss of agricultural labor has been identified as the primary driver of the reduction in farmland utilization strength. However, increases in fertilizer and pesticide investments or changes in crop types can cover the negative influences of labor shortages and improve farmland utilization strength. In addition, the excessive and intensive use of farmland has a negative influence on the ecological environment and national food safety.

Remote-sensing images provide a basis for land resource utilization research. Given the rapid development of satellite sensor technology, high-spatial-resolution (HSR) remote-sensing data have received great attention in the military and civil disciplines. Scene classification has also become an important task for full utilization of HSR image data. The unsupervised learning method examines deconvolutional networks by classifying sensing images from a large-scale dataset. First, the diagram and filter of each image are measured based on the reconstruction error between the minimized input images and the convolution results by applying the deconvolutional networks with light weight. This diagram can capture large amounts of edge and pattern information related to the HSR image. Second, those features with different sizes are aggregated by using the spatial pyramid model (SPM) to maintain the spatial pattern of the HSR image scenes. A differentiated expression of HSR images is obtained by combining initiated weighted deconvolutional models with SPM. Third, the expression vector quantity is included in the support vector machine model to complete the classification. Some researchers have also used a large-scale aerial image dataset for the scene classification of remote-sensing images. The performance of the deep-learning method is then evaluated by using more than 10 000 remote-sensing images and scenes.

The automatic semantic mark problems of HR optical satellite images cannot be easily solved, and the complex and obscure parts of satellite images are difficult to distinguish. Moreover, an annotation method with complete supervision requires a large amount of training samples with HR labels. To address such challenges, researchers have developed a unified annotation framework by conducting an advanced study of features and feature transfer with weak supervision.

The land utilization and land cover changes (LUCC) imitation model analyzes landscape dynamics under various conditions; however, some of its defects remain unaddressed. The future land utilization imitation model clearly imitates the spatial and long-term LUCC, and it is applied through the top-down system dynamics model and the bottom-up cellular automata (CA) model. Adaptive inertia and competition mechanisms are adopted in the CA model to deal with the complex competition and interaction among various land utilization types and to increase the capability of this model to imitate the land utilization mode accurately. Climate change, soil conditions, and other influential factors are also gradually included in this model. Enhancing the identification capability of land utilization optimization in various spaces is expected to become a development trend in future research.

Germany, the USA, and Australia are the three countries that have published the largest number of core papers related to the utilization of land resources under SSP (Table 1.2.6). Meanwhile, Germany, the USA, and Ukraine are the top three countries with the highest average number of citations (Table 1.2.6). Figure 1.2.5 shows that all 10 countries that have published the largest number of core papers on this topic have demonstrated close cooperation.

The Potsdam Institute for Climate Impact Research, Humboldt University of Berlin, and Australia Commonwealth Scientific and Industrial Research Organization have been ranked as the three institutions that have published the largest number of papers on the utilization of land under SSP (Table 1.2.7). Figure 1.2.6 reveals close cooperation among the 10 institutions that have published the largest number of core papers.

As shown in Table 1.2.8, China has published 24 cited core papers and ranked ninth among the 10 countries that have published the largest number of core papers on the utilization of land under SSP.

2 Engineering development fronts

2.1 Development trends in the top 10 engineering development fronts

The global development fronts in the field of engineering management focus on 10 aspects, namely, “electric-vehicle charging management methods and systems,” “intelligent health management methods and systems,” “intelligent connected vehicle technology,” “risk management methods and systems,” “building information modeling (BIM)-based construction management systems,” “monitoring-system development based on positioning technology,” “energy management control methods and systems,” “logistics management methods and systems,” “medical service management methods and systems,” and “intelligent medical management methods and systems”, as listed in Tables 2.1.1 and 2.1.2. These fronts cover a wide range of disciplines, including mechanics, transportation, energy, medicine, construction, and electronics. The fronts of key interpretations include “electric-vehicle charging management methods and systems,” “intelligent health management methods and systems,” “and intelligent connected vehicle technology”, for which current developing states and future trends are discussed in detail in this section.

Table 1.2.6 Countries or regions with the greatest output of core papers on the "utilization of land resources under SSP"

No.	Country/Region	Core papers	Percentage of core papers	Citations	Percentage of citations	Citations per paper
1	Germany	10	76.92%	328	86.09%	32.80
2	USA	7	53.85%	172	45.14%	24.57
3	Australia	5	38.46%	115	30.18%	23.00
4	Japan	5	38.46%	104	27.30%	20.80
5	Netherlands	4	30.77%	83	21.78%	20.75
6	Austria	4	30.77%	82	21.52%	20.50
7	Italy	3	23.08%	54	14.17%	18.00
8	Ukraine	2	15.38%	47	12.34%	23.50
9	South Korea	2	15.38%	26	6.82%	13.00
10	Norway	2	15.38%	42	11.02%	21.00

Table 1.2.7 Institutions with the greatest output of core papers on the "utilization of land resources under SSP"

No.	Institution	Core papers	Percentage of core papers	Citations	Percentage of citations	Citations per paper
1	Potsdam Institute for Climate Impact Research	10	76.92%	328	86.09%	32.80
2	Humboldt University of Berlin	4	30.77%	159	41.73%	39.75
3	Commonwealth Scientific and Industrial Research Organisation	4	30.77%	97	25.46%	24.25
4	Utrecht University	4	30.77%	83	21.78%	20.75
5	PBL Netherlands Environmental Assessment Agency	3	23.08%	71	18.64%	23.67
6	Graz University of Technology	3	23.08%	70	18.37%	23.33
7	International Institute for Applied Systems Analysis (IIASA)	3	23.08%	59	15.49%	19.67
8	National Institute for Environmental Studies	3	23.08%	63	16.54%	21.00
9	Pacific Northwest National Laboratory	3	23.08%	56	14.70%	18.67
10	Mercator Research Institute on Global Commons and Climate Change	3	23.08%	54	14.17%	18.00

Table 1.2.8 Countries or regions with the greatest output of citing papers on the "utilization of land resources under SSP"

No.	Country/Region	Citing papers	Percentage of citing papers	Mean year
1	Germany	89	20.46%	2015.87
2	USA	75	17.24%	2016.07
3	Netherlands	45	10.34%	2016.16
4	Austria	43	9.89%	2016.02
5	UK	41	9.43%	2016.17
6	Australia	34	7.82%	2016.12
7	France	31	7.13%	2015.87
8	Japan	31	7.13%	2016.42
9	China	24	5.52%	2016.42
10	Italy	22	5.06%	2016.18

Figure 1.2.5 Collaboration network among major countries or regions in the engineering research front of "utilization of land resources under SSP"

(1) Electric vehicles charging management methods and systems

With the tight supply and demand for petroleum resources in the world and the increasingly strict regulations on GHG emissions, new-energy vehicles, as represented by electric vehicles, represent an important development trend in the automobile industry. Electric vehicles are driven by motor wheels, equipped with a vehicular power supply, and recharged by either charging or replacing their batteries. However, these vehicles only have a limited amount of electricity stored in their batteries, which restricts their mileage and their large-scale promotion and application. Facilitating the orderly charging of these vehicles is an important research direction for improving the driving stability and reliability of new-energy vehicles, reducing their

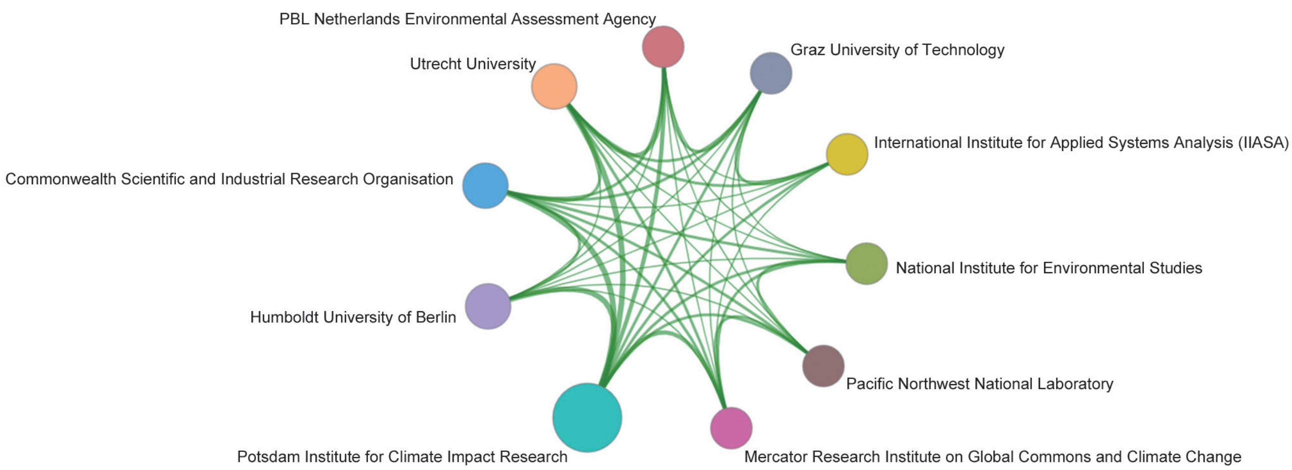

Figure 1.2.6 Collaboration network among major institutions in the engineering research front of "utilization of land resources under SSP"

Table 2.1.1 Top 10 engineering development fronts in engineering management

No.	Engineering development front	Published patents	Citations	Citations per patent	Mean year
1	Electric-vehicle charging management methods and systems	17	104	6.12	2013.24
2	Intelligent health management methods and systems	20	98	4.90	2014.35
3	Intelligent connected vehicle technology	13	30	2.31	2013.77
4	Risk management methods and systems	14	148	10.57	2013.57
5	BIM-based construction management systems	8	58	7.25	2013.88
6	Monitoring-system development based on positioning technology	13	59	4.54	2013.23
7	Energy management control methods and systems	55	279	5.07	2013.40
8	Logistics management methods and systems	42	195	4.64	2013.83
9	Medical service management methods and systems	17	81	4.76	2013.76
10	Intelligent medical management methods and systems	25	177	7.08	2013.84

Table 2.1.2 Annual number of core patents published for the top 10 engineering development fronts in engineering management

No.	Engineering development front	2012	2013	2014	2016	2016	2017
1	Electric-vehicle charging management methods and systems	6	5	4	0	2	0
2	Intelligent health management methods and systems	1	2	7	9	1	0
3	Intelligent connected vehicle technology	3	4	2	2	1	1
4	Risk management methods and systems	4	3	3	3	1	0
5	BIM-based construction management systems	1	2	3	1	1	0
6	Monitoring-system development based on positioning technology	5	4	0	4	0	0
7	Energy management control methods and systems	14	17	13	10	1	0
8	Logistics management methods and systems	5	15	8	11	2	1
9	Medical service management methods and systems	4	1	8	3	1	0
10	Intelligent medical management methods and systems	5	6	4	8	2	0

charging costs, and devising various charging management methods for these vehicles.

(2) Intelligent health management methods and systems

Intelligent health management simultaneously focuses on health promotion and disease prevention. With the rapid development of health management devices and mobile information technologies, a circulatory system that integrates self-health management, health monitoring, health risk assessment, and telemedicine functions is being developed to monitor individual health and to improve the national health level. China has designed various intelligent health management systems, including a personal intelligent health management system based on cloud computing; a multifunction information database health management system based on information integration, the Internet of things, and cloud technology; a multidimensional intelligent health management platform based on Hadoop and virtualized storage technology; and an intelligent health report prompt system based on online-to-offline health management. However, despite its important role in the construction of an intelligent city, the intelligent health management system faces some problems related to quality, information integrity, and information security. The future development of an intelligent health management system requires technological breakthroughs and improvements in the use this system in hospitals, communities, and households all over the country. Integrating big data can also support medical, drug use, nursing, and recovery functions so that such technology can be used in disease prediction, monitoring, and management.

(3) Intelligent connected vehicle technology

Intelligent connected vehicles (ICVs) are equipped with advanced in-vehicle sensors, controllers, and actuators that integrate modern communication and network technologies to realize intelligent information exchange between vehicles and people, roads, cloud platforms, and other vehicles. Given their complex environment awareness, intelligent decision making, and collaborative control and execution, ICVs are considered safe, comfortable, and energy and driving efficient. They are ready to become the next generation of vehicles that will ultimately replace manually operated vehicles. The ICV technology system comprises three levels (environment awareness, intelligent decision-making, and control execution systems), covers three fields (automobile, information interaction, and basic support), and focuses on several key technologies (environment awareness, navigation and positioning, intelligent decision control, and Internet of vehicles). ICV is not only a future development direction of automobile technology but also a development direction of integrating intelligent (automatic driving) and networked (Internet of vehicles) automobiles. In their emerging technology life cycle predictions in the field of intelligent machines, Gartner regards ICV as one of the most promising emerging technologies. Accordingly, countries all over the world have included the development of the ICV industry as part of their national strategies.

(4) Risk management methods and systems

Risk management involves identifying, estimating, and assessing risks, the results of which are used to select and optimize various risk management technologies, effectively control risks, and properly handle the consequences of risk-induced losses to achieve maximum security at a minimum cost. Scholars have adopted various analytical methods in risk management research, including Monte Carlo simulation, analytic hierarchy process, artificial neural network, fuzzy mathematics, genetic algorithms, and Bayesian networks. A fuzzy evaluation method is introduced to reduce the impact of subjective factors on risk assessment results in the process of using expert scoring, the Delphi method, and an analytic hierarchy process. The relationship between individual characteristics (e.g., risk preference, risk attitude, and risk perception) and assessment results must also be examined further to develop relevant psychological research theories and to accurately determine the impact of subjective factors on the risk assessment results. Risk assessment models can also be improved by considering the correlation, dynamics, and transmission path among various risk factors in risk management systems and by considering the manageability, predictability, and other characteristics of risks based on risk occurrence probability and the impact. With the rapid development of management ideas, methods, and modern computer technologies, highly integrated and sophisticated risk management methods have begun to emerge to deal with increasingly complex risk management systems.

(5) BIM-based construction management systems

BIM is used to create building models based on relevant information regarding construction projects and simulates the real information of buildings through digital information simulation. BIM is an integrated process based on design, construction, operational coordination, and project information with the five characteristics of visualization, coordination, simulation, optimization, and graphics. With its continuous application in industry, BIM technology has shifted from a single BIM software application to a multi-software integrated application, from a desktop application to a cloud and mobile client, and from a single application to a comprehensive application. This technology has also started to demonstrate the new features of BIM+ and can be used to realize information sharing among BIM models and build integrated delivery platforms, device information management modules, maintenance management modules, operation and maintenance knowledge base modules, and emergency plan management modules for a variety of purposes. These include improving the efficiency of multi-collaboration; helping construction, supervision, and even property employees identify the physical location of specific equipment; effectively maintaining a large amount of construction equipment information; and managing emergency plans. Web-based BIM systems, which connect progress and cost to a web 3D model during project management, can be used to simulate a web 3D model, create 2D or 3D drawings, generate engineering progress and cost information to portable devices, and improve information liquidity. The construction information is input into the BIM system to generate construction plans automatically and produce construction performance and other information that can help in effectively planning and managing building construction projects and in maximizing the value of such information.

(6) Monitoring system development based on positioning technology

A monitoring system uses various positioning technologies to achieve integrated monitoring of the location, status, and other information related to a monitored object. The main components of such systems include an identification subsystem, a data transmission subsystem, a data storage subsystem, and the integrated display and control subsystem of a monitored object. This system is widely used in cargo transportation, garbage collection, transportation monitoring, public-transport operation, and school bus and student safety monitoring. Positioning technology is divided into indoor and outdoor positioning, of which the former includes infrared, ultrasonic, RFID, Bluetooth, Wi-Fi, ZigBee, and ultra-wideband technologies, while the latter includes GPS and Beidou civil positioning technologies. Monitoring systems based on positioning technology are expected to attract wide applications in engineering management, especially in on-site construction safety management. The safety monitoring of personnel and equipment on construction sites has several primary considerations, such as positioning accuracy and cost. GPS has a positioning accuracy of 10 m, while Beidou civil positioning has an accuracy that can reach within 10 m of a plane and 10 m of the elevation without base stations. When a base station is deployed, the sharp rise in costs cannot meet the needs of the project. In this case, adopting Bluetooth plus phased-array technology with a decimeter positioning accuracy is highly feasible. By deploying secondary base stations and positioning tags, position monitoring can be used to track the movements of personnel and identify the specific location of equipment at a reasonable cost.

(7) Energy management control methods and systems

Energy management is a process of developing strategies for national energy and economic development and of monitoring the implementation of such strategies at various stages. On the one hand, a sufficient energy supply must be ensured to provide energy support for national economic development. On the other hand, energy must be effectively and reasonably used to promote healthy development and to improve the quality of the living environment and social economy. The major development directions in energy management are mainly concerned with energy performance contracting (EPC), information energy management systems, and distributed energy management systems. EPC, also known as EMC in China, is a new energy-saving mechanism that was developed based on the demands of the market. In this mechanism, a professional energy-saving service company signs a contract with an energy-using company and provides the diagnostic design and necessary financing for conducting energy-saving projects; upgrading, installing, procuring, and commissioning construction equipment; training operations management personnel; measuring and verifying energy savings; and ensuring a high energy saving rate. Meanwhile, the energy-using company aims to achieve high energy-saving efficiency to finance its project investments and to ensure the profitability of the energy-saving mechanism adopted in the market. Supported by the Internet and logistics information technologies (e.g., computer networking and database technologies), information energy management systems have several functions, including data maintenance, query, statistics, and analysis, as well as energy-saving management. Based on the power generated from distributed renewable energy, the distributed energy management system constructs an energy Internet system that can read real-time, high-speed, and bidirectional power data and provide renewable energy access. This energy Internet system comprises an intelligent energy management system, distributed renewable energy, energy-storing devices, converter devices, and smart terminals. Utilizing such technologies can ensure low carbon emissions and effective energy consumption. A comprehensive and efficient overseas energy supply auxiliary system must also be developed to improve energy supply management in China.

(8) Logistics management methods and systems

Logistics refers to the physical flow of goods from their origins to their intended recipients. Basic functions in logistics include transportation, storage, loading, unloading, handling, packaging, circulation, processing, distribution, recycling, and information processing. Given the increasingly important role of logistics in modern socioeconomic development, advanced logistics management methods and systems have attracted wide application prospects. The deepening application of the Internet of things and mobile Internet along with Internet-driven transformations in business and management have created several challenges that hinder the application of logistics management methods and systems. From the perspective of enterprise logistics, upstream and downstream logistics resources must be integrated with service cooperation under the supply chain structure to build a supply chain logistics integration control platform that can serve as the basis of enterprise operations. From the perspective of living logistics, broad logistics resource sharing and service cooperation are feasible future directions. From the perspective of regional logistics management, the effective organization of regional logistics resources and the optimization of multi-modal transport organization based on big data and modern information technology not only guarantee efficient logistics services and high energy savings but also require consideration of the effective utilization of regional space resources. The organic integration of surface air with the underground intelligent logistics system presents an important future direction in this area. Piecemeal and single-link management methods for logistics technologies have reached maturity, while the wide-area logistics service model, which is supported by the block chain technology and the comprehensive optimization decision-making method, must be developed further. Applying logistics dynamic risk analysis and control methods in a big-data environment is expected to improve the real-time quality of logistics services.

(9) Medical service management methods and systems

Medical service is an umbrella term for various clinical services, such as diagnosis, treatment, rehabilitation, and nursing, which are provided by qualified medical institutions and their medical staff. Medical service management methods and systems aim to improve the quality and efficiency of medical services by using science and technology and advanced medical management modes. The development of medical service management methods and systems is currently focused on informatization, intellectualization, integralization, and precision. These methods highlight the use of the Internet and technologies for constructing a regional medical service big-data and cloud-computing platform as well as an integrated and intelligent medical service delivery system. To provide remote and accurate medical services, these methods must balance the standardization, precision, and complexity of medical problems. Guided by medical best practices and the requirements of evidence-based medicine and cost control, standardized clinical pathway management has been implemented to reduce the space for flexible treatment. The application of big data and the Internet is further improving the intelligence and precision of hospital diagnosis and treatment systems, reducing service delays and resource wastage, and improving the service experience and satisfaction of patients. However, given the complexity, uncertainty, and differences in their occurrence and development, chronic diseases are difficult to predict. Rising medical costs and other issues related to protecting the rights and interests of patients present additional challenges to the improvement of medical service management methods and systems.

(10) Intelligent medical management methods and systems

Intelligent medical management realizes information interaction among medical service elements by using advanced artificial intelligence, the Internet of things, and data fusion technologies and realizes the intellectualization and automation of clinical services through digital means. Although the development of intelligent medical management methods and systems is still in the exploratory stage, the in-depth application of artificial intelligence and big-data technology in the medical field is overwhelming. Given the lack of high-quality human resources, the inefficiency of human services, and the wastage of health resources, the emergence of intelligent medical management systems is expected to further enhance the efficiency and quality of medical services, optimize the allocation and sharing of health resources, and reduce social medical costs. Intelligent medical management systems have produced promising results in intelligent diagnosis, intelligent treatment, intelligent nursing, and intelligent healthcare and have been successfully used to launch intelligent service projects, such as intelligent medicine and intelligent wearing. Such systems also enhance the efficiency and precision of clinical decisions and medical practices by empowering and providing assistance to medical personnel. However, the development of intelligent medical management systems is affected by the complexity of the medical environment and certain health problems, as well as the ever-changing degree of cooperation among various medical service elements. Given these problems, intelligent management systems cannot adapt well to complex medical practices. The application of artificial intelligence in the field of medical services remains weak, unable to conduct multitask learning, and dependent on big-data learning. However, with the development of precision medicine, small-data learning is expected to become a future development trend.

2.2 Interpretations for three key engineering development fronts

2.2.1 Electric-vehicle charging management methods and systems

Electric vehicles have unique advantages over traditional fuel vehicles, such as their low pollution, low noise, high energy efficiency, and easy maintenance. These vehicles meet the travel needs of people while complying with traffic network flow control. A large number of these vehicles are connected to the power system. When charging the batteries of these vehicles, the power is taken as a load from the power grid and then fed back as a power source during discharge. The orderly charging and discharging of electric vehicles can reduce the peak–valley difference of power systems and eliminate the intermittent generation of renewable energy. Therefore, studies on charging management methods for electric vehicles can significantly improve the operational efficiency of power and transportation systems and promote the coordinated development of energy, economy, and environment.

Given the differences in the number, users, and driving coverage of electric vehicles, their charging methods also demonstrate various characteristics, while their charging demand shows great uncertainty. The current power supply modes for electric vehicles include slow charging, fast charging, and battery replacement. These vehicles show clear differences in their charging time, charging cost, and battery life under different supply modes. The electric-vehicle charging management method aims to minimize the charging cost and facilitate the optimization of charging facility pricing decisions, site selection, and volume. The safety constraints of the power system must also be considered to meet the driving demand of electric vehicles, realize their economic operation, and enhance the economic efficiency of their charging and replacing stations.

(1) Orderly charge and discharge optimization decision for electric vehicles to meet driving demand. A charging and discharging decision-making method was proposed to minimize the charging cost and power peak–valley difference, to reduce the negative impact of the power system peak–valley difference resulting from disordered charging and voltage drop in local areas, to improve the operating efficiency of the power system, and to meet the driving path demand of electric vehicles while considering their battery capacity and the mutual exclusion of their charge and discharge states.

(2) Charging station pricing decision considering the demand response of electric-vehicle users. A combination package for charging station parking, charging, and discharging was designed while considering the differences in the demands of electric-vehicle users, while a pricing decision model with the minimum operating cost of the charging station was devised to guide the orderly charging and discharging of electric vehicles. This model is expected to increase the economic benefits of charging stations and reduce the charging costs for users.

(3) Charging and replacing power station planning while considering the characteristics of electric-vehicle energy replenishment. By acting as the node service facility of a traffic network and the load/power node of the power network, the battery charging and replacing power station can improve the charging efficiency of electric vehicles via reasonable location planning. Based on the charging demand characteristics of electric vehicles and by considering the constraints of traffic network flow and power network operation, a site selection and volume decision model for the multi-objective charging and replacement of power stations was established while considering the construction and operating costs of new road networks and power grids. This model can determine the charging method that satisfies the charging requirements of different electric vehicles, reduce the electricity purchase costs of electric-vehicle users, and provide technical support for the planning and construction of electric-vehicle charging and battery-replacing service facilities.

The USA, Japan, and various European countries are actively developing electric-vehicle charging management methods and investigating their application. Studies in the USA have primarily focused on improving electric-vehicle battery systems. In 2012, Elwha LLC developed a battery management system for electric vehicles that can be remotely manipulated. By loading data packets on the battery system and recording battery running data, this system can evaluate the usage state of the battery and provide users with charging strategy recommendations. Studies in Germany mainly focused on optimal charging path planning for electric vehicles to reduce their charging time and cost. This strategy relies on the advantages of the automobile and power industries to promote the development of the electric-vehicle industry. By 2013, Germany built 4,454 charging stations to provide electric vehicles with several options. Robert Bosch GmbH developed an optimal charging path device based on battery charging state and navigation data. This device comprises a battery state output and a continuously updated navigation data output system. Based on information regarding the remaining battery power and navigation of the electric vehicle, this device can determine the optimal charging path to the destination of the users, thereby saving charging time and cost. Studies in Japan have focused on the scientific management of electric-vehicle battery parts. In 2012, Toyota Motor Corporation developed an electric-vehicle battery parts management system that comprises a vehicle management device, a data storage device, and a controller. This device can record the usage state of various battery parts and prompt users to repair and replace worn or damaged parts as soon as possible. Scholars are currently examining ways to improve the battery performance and charging facilities for electric vehicles. However, studies on the sharing, pricing, and planning of electric-vehicle charging infrastructure are still in their infancy. Therefore, a pricing and planning decision theory system that can guide electric-vehicle users in the sharing and orderly charging or discharging of vehicles and charging facilities is yet to be developed. Thus, research on the sharing, pricing, and planning of electric-vehicle charging infrastructure is currently in demand and is expected to provide important scientific and economic value in the future.

Japan, South Korea, and the USA are the top three countries/regions that have published the largest number of core studies on electric-vehicle charging management methods and systems, with China ranking fourth (Table 2.2.1). Figure 2.2.1 shows a low level of cooperation among those countries that have published core papers on this topic. However, a close cooperation is observed between Israel and Switzerland.

2.2.2 Intelligent health management methods and systems

Since the 1960s and 1970s, management scholars in Europe and the USA have examined management problems in the field of healthcare. The health demands and medical expenditures of individuals continue to increase as they age, thereby imposing an unprecedented pressure on each country. During the past decade, many scholars have begun to examine the management problems in the field of healthcare, including the auxiliary optimization of medical decision making, the optimization of public health policies for management, and the optimization of key medical resources. The rapid development of mobile Internet, cloud platform, and smart wearable device technologies has enabled real-time access to individual health information and the analysis of massive medical information, based on which intelligent health management methods and systems have been developed. The intelligent health management method and systems can provide comprehensive services, such as collecting, storing, and analyzing health data; providing health consultation services to residents; and supporting the intelligent management of chronic diseases and key hospital resources. The following sections discuss the four aspects of individual health intelligent management systems, intelligent hospital systems, intelligent management systems in community hospitals, and intelligent pension systems.

(1) Individual health intelligent management system. Intelligent health management methods and systems have focused on the intelligent management of individual health during the past five years. These methods primarily collect personal health information and physiological indicators, such as blood glucose, blood pressure, pulse, blood oxygen, BMI, and waist-to-hip ratio, in real time by using intelligent wearable devices, and then these data are sent to a health management platform or terminal equipment via Wi-Fi or Bluetooth technology. These data are then collected and analyzed, and users can search for personal health data, dietary recommendations and recipes, fitness advice, and health tendency diagrams by visiting a website or using mobile applications. When they begin showing abnormal symptoms, such as a physical signs index that exceeds the usual limit, users receive an SMS message reminding them to pay attention to their health. Afterward, they can respond to these health threats in a timely manner by adjusting their sleeping and eating habits.

(2) Intelligent hospital system. Intelligent health devices can be linked to an intelligent cloud hospital to give their users access to a database that covers their entire diagnosis and treatment processes. These patients can then register and receive diagnosis and treatment in an intelligent hospital system, while doctors can perform telemedicine and other functions through this system. In this way, the working efficiency of medical professionals can be improved, and the urgent nature of medical resources can be eased. The intelligent hospital system can also store the personal health records of each patient in a cloud platform, and users can upload additional information to these records by using portable devices. This functionality not only allows doctors to re-examine and adjust the treatment and medication for their

Table 2.2.1 Countries or regions with the greatest output of core patents on the “electric-vehicle charging management methods and systems”

No.	Country	Published patents	Percentage of published patents	Citations	Percentage of citations	Citations per patent
1	Japan	7	41.18%	23	22.12%	3.29
2	South Korea	3	17.65%	33	31.73%	11.00
3	USA	3	17.65%	6	5.77%	2.00
4	China	2	11.76%	7	6.73%	3.50
5	Switzerland	1	5.88%	31	29.81%	31.00
6	Germany	1	5.88%	4	3.85%	4.00
7	Israel	1	5.88%	31	29.81%	31.00

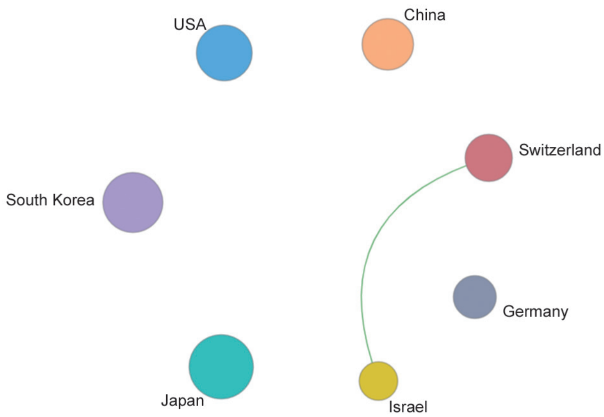

Figure 2.2.1 Collaboration network among major countries or regions in the engineering development front of "electric-vehicle charging management methods and systems"

patients but also helps patients understand changes in their health and take appropriate actions.

(3) Intelligent management system in community hospitals. Community hospitals are called "gatekeepers" in Europe and the USA. These institutions provide basic medical and healthcare services, such as prevention, recovery, and health education. The intelligent management system in community hospitals collects health or medical information from patients either online or offline, constructs and stores their health records, monitors their health throughout their whole life cycle, and allows them to check on their health records and seek medical treatment online at any time. The medical staff can also learn about the personal and group health status of community residents by using this system. For instance, when the residents in communities under their jurisdiction begin to show abnormal physical conditions, these medical staff can call on doctors to examine and provide health recommendations to these respondents relating to their diet, medication, or treatment. Moreover, when an epidemic is predicted to affect a community, these medical professionals can immediately implement the necessary intervention measures through this system. China has no traditional family healthcare system, and only few families in the country periodically undergo physical examination. By storing health records in a cloud platform, the intelligent management system can be used as a complete family healthcare and prevention system by commercial health insurance agencies, family doctors, and community hospitals. Doctors can also arrange appointments, periodically diagnose each family member, and regularly provide long-term services. Community hospitals can offer offline clinical services for certain procedures that need to be administrated personally, such as blood sampling. Community hospitals establish a closed loop among online diagnosis, offline guidance, and insurance payment, thereby providing one-stop medical treatment solutions to residents.

(4) Intelligent pension system. Smart health equipment also has a crucial function in pension enterprises. An intelligent health management system can collect basic health information from the elderly to establish a comprehensive information database to monitor the health status of this vulnerable population and to conduct regular tests to ensure their well-being. By using wearable intelligent health portable devices, the elderly can immediately ask for urgent assistance, household care, housekeeping, mental care, and health management services. In this way, communities can effectively integrate their social service resources and establish a comprehensive pension service system.

Given the advances in artificial intelligence, intelligent health management methods have recently become a hot research topic in the area of medical services. However, these methods are still in their infancy. Further explorations on health management may be extended to personal health information collection and management; remote health consultation; medical, clinical appointment, and registration services; and health management services for the elderly. These methods also provide many benefits, such as early illness prediction, smart diagnosis, medicine use management, and epidemic prevention. Therefore, future research and developments in this area must focus on smart medical systems and integrate intelligent health management systems into intelligent medical systems. By using intelligent health management systems, hospital managers can collect and store large amounts of medical data (including clinical and management data) that provide a foundation for intelligent medical treatment (including intelligent medical decision making and intelligent medical management). The condition of patients can be predicted, the decisions of medical professionals can be optimized, the misdiagnosis rate can be reduced, and the efficiency of medical services can be improved by conducting a machine-learning and intelligent analysis of personal health data and examination results.

China and South Korea are the top two countries/regions that have published the largest number of public patents related to intelligent health management methods and systems. Specifically, China has published 19 core patents in this area (Table 2.2.2). Among those institutions that have published such patents, Anycheck Information Technologies Co., Ltd. has published six, of which two have been cited (Table 2.2.3).

2.2.3 Intelligent connected vehicle technology

ICVs have been in operation for nearly 80 years since the emergence of the world's first automatic driving concept car. After going through the phases of concept launch, basic research and development, and running tests, ICVs entered the phase of the market economy. With the rapid advancement of Internet technologies and the continuous development of other technologies, such as communication and perception, ICV technology has embarked on the development path of "smart plus connected" unmanned vehicles.

The development of ICV technology has two major aspects. On the one hand, intelligence (i.e., automatic driving) is expected to be realized gradually. The International Society of Automotive Engineers (SAE) divides automatic-driving technology into five development stages from driving support to fully automatic driving, with "unmanned driving" being the highest stage (Level 5). On the other hand, network connection (Internet of vehicles) aims to realize an intelligent information exchange among vehicles and between vehicles and roads.

The development of unmanned driving is driven by two technical factions, namely, ADAS, an independent intelligent technology represented by traditional automobile companies, such as General Motors, Volkswagen, and Mercedes-Benz, and artificial intelligence and network technology, which is represented by Internet companies, such as Google, Apple, and Baidu. ADAS is gradually realizing intelligent unmanned driving based on existing automobile technologies, sensing, and machine decision making, while artificial intelligence and network technology controls and transforms traditional vehicles through computers and the Internet. Although these technologies have different starting points, they are eventually merging to achieve completely unmanned driving.

ICV technology integrates technologies in the fields of automotive engineering, artificial intelligence, computers, microelectronics, automatic control, communication, and data platforms. This technical complex also integrates environment awareness, planning decision making, control execution, and information interaction with an interdependent technology chain and an industrial chain system.

The ICV technology system comprises three levels, namely, the environment awareness system, intelligent decision-making system, and control execution system, and it is divided into three directions, namely, connected vehicle, autonomous vehicle, and ICV, depending on its technology development path. ICV combines the technical advantages of autonomous and connected vehicles and utilizes technologies in the fields of automobile, information interaction, and basic support. Implementing these functions greatly depends on key

Table 2.2.2 Countries or regions with the greatest output of core patents on the "intelligent health management methods and systems"

No.	Country	Published patents	Percentage of published patents	Citations	Percentage of citations	Citations per patent
1	China	19	95%	97	98.98%	5.11
2	South Korea	1	5%	1	1.02%	1.00

Table 2.2.3 Institutions with the greatest output of core patents on the "intelligent health management methods and systems"

No.	Institution	Country	Published patents	Percentage of published patents	Citations	Percentage of citations	Citations per patent
1	Anycheck Information Technologies Co., Ltd.	China	4	20%	8	12.25%	2
2	Hangzhou Yinjiang Intelligence Medical	China	2	10%	5	5.10%	2.5
3	Jiaxing Zhiheng Precision Instruments Co., Ltd.	China	2	10%	7	7.14%	3.5

technologies, including environment awareness, navigation and positioning, intelligent decision making, control execution, information fusion, and Internet of vehicles.

(1) Environment awareness and navigation and positioning technology. This technology is mainly used for the real-time navigation and positioning of intelligent connected vehicles in motion. The environment awareness system combines advanced communication, information sensing, and computer control technologies; uses the main vehicle sensors (e.g., cameras, millimeter-wave radars, laser radars, and ultrasonic) and the "V2X" communication system to sense the surrounding environment; and provides a decision-making basis for intelligent connected vehicles by extracting road condition information and detecting obstacles. In auxiliary and driverless systems, the Beidou navigation system is combined with electronic maps, radio communication networks, and computer vehicle management information systems. Given its highly accurate positioning, the Beidou system provides high-precision positioning solutions with low cost and wide coverage that allow automatic-driving vehicles to implement certain functions, such as vehicle tracking and traffic management.

(2) Intelligent decision-making technology. The ICV decision-making control technology offers decision guidance control over driving behaviors by processing and collecting information. Its technical system involves key technologies, such as information fusion, path programming, and vehicle control technologies, and it is treated as a core part of the whole system of ICVs.

(3) Control execution technology. Integrated vehicle control can be realized by controlling the execution actions of vehicle power, chassis, and electronic appliances.

(4) Information fusion technology. Big data are a premise of ICV decision making. Information fusion technology improves the reliability and security of the system and the accuracy and credibility of the information by integrating data from various sources.

(5) Internet of vehicles technology (i.e., networked). The Internet of vehicles is based on in-vehicle networks, inter-vehicle networks, and vehicle-mounted mobile Internet. It facilitates wireless communication and information exchange between vehicles and people, vehicles and roads, and vehicles and cloud platforms, as well as among vehicles, based on agreed communication protocols and data interaction standards. This technology also creates an integrated network of intelligent traffic management, intelligent dynamic information service, and vehicle intelligent control. The Internet of vehicles adopts several key technologies, such as sensors and sensor information integration technologies, open and intelligent vehicle terminal system platforms, speech recognition technology, server computing and service integration technologies, communication and application technologies, and Internet technology.

Several countries, including the USA, Japan, and European Union countries, have included the development of the ICV industry in their national strategies. *The US Intelligent Transportation System Strategic Plan (2015–2019)*, which was released in the USA in 2015, identifies the Internet of vehicles and vehicle automation as two strategic priorities. In 2011, the European Union promulgated the *White Paper on EU Integrated Transportation*, which focuses on the development of vehicle intelligent safety, informatization, and traffic safety management. It takes information security, information reliability, and large-scale demonstration application verification as key technology research areas. Launched in 2013, the *Horizon 2020 Research Plan* promotes the development of ICV technology from the aspects of standard systems, infrastructure, and network security. Japan began studying ICVs and intelligent transportation systems in the 1990s. In 2013, its strategy for establishing a state-of-the-art IT country included some elements and targets for ICVs. In 2020, Japanese automatic-driving cars are expected to appear on highways. In the ICV technosphere, Europe, the USA, and Japan have formed a tripartite confrontation. Specifically, the USA is focusing on networking and has rapidly developed its V2X-based networked automotive industrialization capability given the strong R&D system of its government. Europe has established some world-class suppliers of automotive electronic components and created vehicle companies with relatively advanced autonomous self-driving technologies. Japan has actively promoted and improved automatic-driving technology with the help of its excellent transportation infrastructure.

Compared with these developed countries, China started relatively late in ICV technology research and development. In its *Made in China 2025* plan launched in 2015, China lists ICVs, energy-saving vehicles, and new energy vehicles as important strategic directions for the development of its automobile industry. The plan clearly states three objectives: (1) mastering the overall and key technologies of intelligent-assisted driving by 2020; (2) establishing a relatively complete ICV independent research and development system, production supporting system, and industrial cluster; and (3) transforming and upgrading the automotive industry of the country.

From the technological perspective, the transition from manual mechanical operation to electronic information system control is accelerated by the wide application of artificial intelligence, information communication, positioning and navigation, big data, cloud computing, and other technologies in the automotive field. This trend is inevitable in the development of ICV technology. The traditional automobile industry conforms to the general trend and accelerates its cross-border cooperation with information communication, intelligent transportation, and other fields along with the rapid development of Internet technology and the continuous development of other technologies, such as communication and perception. The automobile industry chain faces reconstruction; the value chain continues to expand; and the industrial development is driven by intelligence, platforms, and networks. The ICV industry is a new type of industry that is deeply integrated in the fields of automobiles, electronics, information, transportation, positioning and navigation, network communication, and Internet applications. Accordingly, ICVs have become a key topic in global innovation and future development.

China, South Korea, and Japan are the three countries/regions that have published the largest number of core patents related to ICV technology, among which China takes the lead with nine patents (Table 2.2.4). Each organization listed in Table 2.2.5 has produced only one patent. Among these organizations, Tianjin Anlian Chengtong Information Technology Co., Ltd., JGJT, and Shanghai Zheshan Electronic Technology all received five citations (Table 2.2.5). A limited degree of cooperation is observed among these organizations, as shown in Figure 2.2.2.

Table 2.2.4 Countries or regions with the greatest output of core patents on the “ICV technology”

No.	Country	Published patents	Percentage of published patents	Citations	Percentage of citations	Citations per patent
1	China	9	69.23%	24	80.00%	2.67
2	South Korea	3	23.08%	4	13.33%	1.33
3	Japan	1	7.69%	2	6.67%	2.00

Table 2.2.5 Institutions with the greatest output of core patents on the “ICV technology”

No.	Institution	Country	Published patents	Percentage of published patents	Citations	Percentage of citations	Citations per patent
1	JGJT	China	1	7.69%	5	16.67%	5
2	Shanghai Zheshan Electronic Technology	China	1	7.69%	5	16.67%	5
3	Tianjin Anlian Chengtong Information Technology Co., Ltd.	China	1	7.69%	5	16.67%	5
4	Hunan Chuanxin Electronic Technology Co., Ltd.	China	1	7.69%	3	10.00%	3
5	WSGC	China	1	7.69%	3	10.00%	3

JGJT: Jinan Iron & Steel Group Co., Ltd.; WSGC: Wuhan Iron and Steel (Group) Kunming Iron and Steel Co., Ltd.

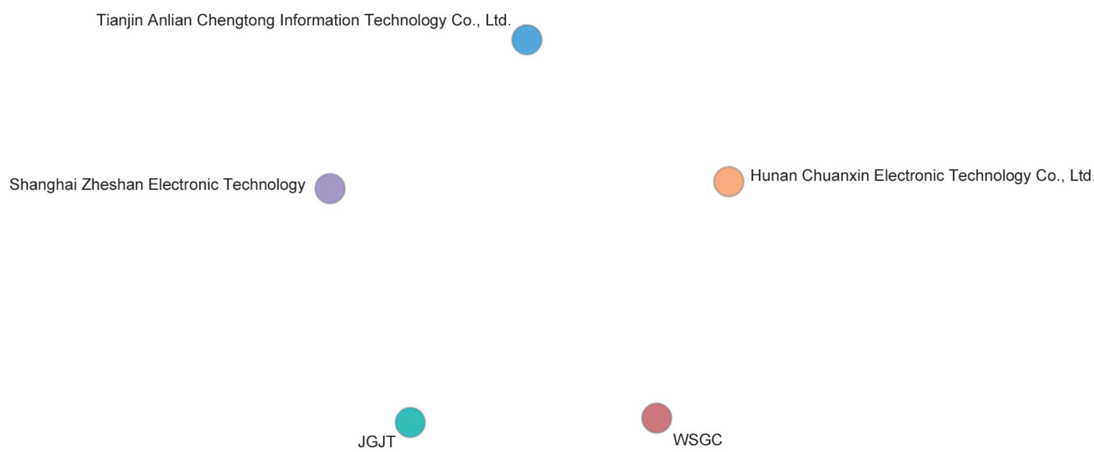

Figure 2.2.2 Collaboration network among major institutions in the engineering development front of “ICV technology”

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