Future of the Manufacturing Industry with the Paradigm Shift in the Industry and Strategy

Dong-hyeok Seo, Yun-hee Choi, Gyeong-yu Kim, Sang-hun Kim,
Won-shik Hwang, Nam-hee Choi

1. Research Background and Objectives

The emergence of Apple's iPhone revolutionized the manufacturing sector, ushering in sweeping changes into production, management, and market rules. Just as the evolution of digital technology has transformed the core technologies and capabilities of manufacturing, a rapid transition of values is now afoot, from technology orientation to customer orientation, from cutting-edge techniques to diversity and user-friendliness, and from exclusivity and individuality to openness and compatibility. The pace of this transition will only accelerate in the coming years.

The so-called "third industrial revolution," spearheaded by information and mobile technologies, will give way to a fourth, in which all products and technologies will become connected largely through the Internet of Things (IoT) and robotics. It will support the "Second Machine Age" and the coexistence of humankind and machinery, while 3D printing, big data, the IoT, intelligent and emotional robots, and cognitive convergence will become the new bases of innovation. With greater convergence heralding the dawn of this new smart age, manufacturing will flourish not through distinctiveness or simply touting more high-tech, but through its capabilities for customer value maximization, mass customization as opposed to mass production, and openness and compatibility as opposed to product exclusivity.

In enhancing the competitiveness and sustainability of manufacturing, it is critical to proactively meet the new challenges presented by this industrial paradigm shift with strengthened core capabilities. This study analyzes the likely trends and developments of four prospective industries in the next 10 to 15 years, and then uses the analysis to forecast the future of manufacturing. The four industries subjected to our analysis are in their incipient or emerging phases and are expected to shape the future of manufacturing—namely, futuristic (smart) cars, convergence materials, convergence-based bio and smart healthcare (biomedical services), and IoT and IT convergence.

2. An Industrial Paradigm Shift and the Advancement of Manufacturing

□ The industrial paradigm shift

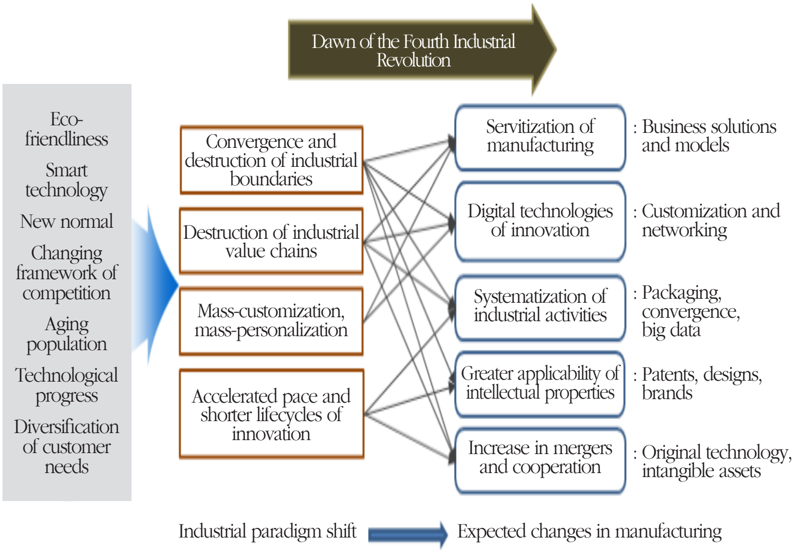
As the third industrial revolution gives way to the fourth, we are witnessing a wide range of new industrial developments and phenomena. IoT technology, in particular, will serve as the central catalyst of this change, after having become mainstream in 2015. The fourth industrial revolution will exert a profound impact on the manufacturing sector's environment and strategies. We can expect the following paradigm shifts from this groundbreaking revolution.

First, convergence will demolish barriers among industries. Convergence with eco-friendly, energy-saving, multipurpose and smart technologies will render old industry distinctions meaningless. Indeed, the growing ambiguity of inter-industry boundaries is a foremost phenomenon associated with industrial convergence. As a consequence, competition will begin taking place at the level not of individual industries, but of convergence, forcing us to reconceptualize industries.

Second, innovation will occur at an accelerated pace and have shorter lifecycles. Innovation itself has become something of a norm and a core requirement for business competitiveness. As companies strive to overcome increasingly fierce competition, changing rules of competition, low economic growth, and quicker drops in post-innovation profitability, innovation will occur with much shorter lifecycles. Even now businesses are needing to generate shorter-term competitive advantages, caught in an obligation to continually innovate.

Third, the conventional value chain will eventually collapse. As it becomes impossible for businesses to handle all necessary manufacturing activities on their own, they will naturally partake in more cooperative ventures with one another. This, in turn, will break up the sequential order of the corporate value chain, mixing and complicating the processes along the chain. The growth of novel technologies, such as 3D printing, will revolutionize the industrial structure, erasing the boundaries that marked the con-

Figure 1. Changes in Manufacturing Due to the Industrial Paradigm Shift



ventional scopes of business.

Fourth, the concern with mass-production will give way to a focus on mass-customization and mass-personalization, with production increasingly oriented toward products and services tailored to individual consumers' needs. Making this evolution possible is 3D printing technology, which will facilitate and lower the cost of the standardization and modularization necessary to produce everything imagined on a repeated basis. Local Motors, an American startup that produces electric vehicles using 3D printers, is an example drawing much attention in this regard.

The industrial paradigm shift will transform the manufacturing sector by promoting the servitization and diversification of business models, making digital innovation the leading force of change, systematizing production increasing the applicability of intellectual properties, and prompting mergers and cooperative efforts to find new technologies and enhance business synergies.

3. Future Positioning and Prospects of the Analyzed Industries

□ Smart cars

More than any other industry in the manufacturing sector, the automobile industry is faced with the most acute changes to its century-old history with the recent industrial paradigm shift. As the technological gap among automakers is increasingly narrowing, they have had to differentiate their vehicles in aspects other than performance, such as safety and convenience. In the meantime, more rigorous environmental and safety regulations, complaints over traffic congestions, and the growing number of elderly and women drivers have increased demand for other unprecedented changes.

In the past, a car simply ran on the appropriate combination of an engine, fuel, and a transmission. Today, electronics and information technology are used to enhance the safety and convenience of driving. In the future, the advancement of the cloud service and the spread of IT devices will enable constant communications between the car and the external environment, enabling such innovative functions as autopilot driving. Accordingly, the focus in auto manufacturing will shift from mechanics to information and communications technology (ICT) and convergence, which, in turn, will usher in structural changes and the expansion of industrial ecosystems.

As cars evolve from simple means of transportation into smart devices with wheels, automakers, automotive parts manufacturers, and ICT businesses are collaborating to an unprecedented degree. The rapid changes in the auto industry have opened up the market to new players, while competition and collaboration among automotive businesses is expanding industry boundaries. Since cars are connected to external networks today, automakers are compelled to enhance their competitiveness in non-traditional functions and features, such as the service platform. This has led ICT giants like Apple, Google, and Microsoft to look for new growth pathways within the auto industry.

The emergence and distribution of smart cars heralds profound changes for the entire urban system. The connection of cars to mobile communications networks has significantly shifted the center of competition in the auto industry from hardware to software and systems. Service platforms are the new center of competition. Smart cars are thus most likely to evolve in the direction of the most efficient convergence of automobiles with ICT. Although this new track of evolution will outdate conventional growth strategies based upon vertical integration and internalization, automakers will need to collaborate with businesses in other industries to find and develop innovative features that add value to their cars.

In Korea, however, the exclusive tendencies and the vertically integrated structure of industries is going to hinder collaboration and convergence among different industries. The Korean strategy of vertical integration and internalization is proving to be ineffective for today's research and development (R&D) process, which requires an interdisciplinary approach combining multiple industries and functions. The auto industry's paradigm shift, with the center of competition moving from hardware to software, makes it difficult for automakers to achieve innovation by themselves. Without change, Korean automakers that have until now focused almost exclusively on manufacturing are at risk of falling behind their international counterparts. It is critical for Korean automakers to gain interdisciplinary understanding and organize horizontal collaborations.

□ Convergence materials

The materials industry forms the bedrock of the entire manufacturing sector. As such, it is both part of the manufacturing infrastructure and a horizontally integrated industry. The materials industry encompasses a wide scope of business concerns with diverse technological origins and very complex and different technological tasks. Of the 19 “top growth engines for the future” listed in the “Growth Engines for the Future: Industrial Engine Implementation Plan,” announced by the Korean government as part of its Three-Year Economic Innovation Plan in March 2015, the growth engines of the materials industry are convergence materials and state-of-the-art material processing systems.

Among cutting-edge materials, titanium is regarded as a versatile futuristic material with a wide range of applications, even under extreme conditions. Titanium is thus generating a lot of interest not only in the convergence materials industry, but also among makers of state-of-the-art materials processing systems. There are a number of important trends afoot in the materials industry today: (1) integration of material production and processing systems, (2) accelerated and growing collaboration among suppliers, processors, and end users of materials, (3) significant growth in the demand for cutting-edge materials, and (4) convergence of smart technologies and services in production and processing in response to growing environmental and other regulations.

Accompanying these trends is the shift from capital and technology to novel ideas and designs as sources of innovation. Automakers and manufacturers of other finished goods are now undertaking collaborative research with parts and materials manufacturers, and in some cases setting up consortia. This tendency toward interdisciplinary collaboration has even begun to spill over into the service sector. In the materials industry, the formerly unilateral direction of innovation (e.g., from goals to means or from causes to effects) is also becoming more diverse and complex, involving more and more interactions among processes, organizations, and functions.

Despite the prospects for new growth engines in emerging convergence materials industries, and despite the economic importance of these new industries, risks persist because of the concentration of relevant resources and technologies in certain countries and because of the need to conduct time-consuming tests on the reliability of new systems. Even so, the cycle of innovation in new materials industries continues to grow shorter. In the interest of greater compatibility between downstream industries related to materials convergence with upstream industries, the horizontal convergence of value chains will persist in the materials industry in the coming years.

□ Biomedical services and healthcare

The growing concern with the quality of life, population aging, and the prevalence of chronic diseases will continue to drive up healthcare spending, contributing to the expansion of the global biomedical market. Frost and Sullivan (2015) projected that the international healthcare market—encompassing pharmaceutical products, medical devices, and medical IT (but excluding hospital services)—would grow by five percent from USD 147.62 billion in 2014 to USD 155.05 billion in 2015. Although the market for IT-healthcare convergence continues to grow at an explosive pace in Asia-Pacific, the Korean market is unlikely to grow as quickly due to existing regulatory and social barriers. Currently, the absolute size of the Korean market remains marginal (KRW 9.0333 trillion as of 2013), which is only a small fraction of the Korean gross domestic product (GDP).

Nevertheless, the Korean biomedical industry's average annual rate has been 15.32 percent since 2000 thanks to the government's strong backing and investment. It has begun to produce some remarkable achievements in the recent years too, especially the export of technology by Hanmi Pharmaceuticals. Starting with its First Biotechnology Development Plan of 1994, the Korean government has been increasing its investment in biomedical R&D at an average rate of 22.3 percent a year, investing KRW 2.5284 trillion in 2013 and KRW 2.3389 trillion in 2014. Thanks to the government's determination and continued investment, the Korean biomedical industry has accumulated a sizable amount of knowledge assets and competitiveness, and it has begun to produce tangible results from its R&D projects. The amount of investment in innovative startups and the merger of pharmaceutical and biotechnology businesses is also on the rise.

Yet the Korean biomedical industry still falls behind its counterparts elsewhere in the world, particularly in terms of demand and the ability to pioneer new markets. In 2015, the Korean convergence bio and smart healthcare industry scored 3.75 points out of a five-point scale in terms of the supply capability and 1.875 points in terms of the ability to meet demand. Nevertheless, the Korean industry's supply capability is anticipated to grow to 80 percent (4.0 points) of the American score, as is the ability to meet demand (4.0 points), by 2025.

☐ IoT

We are already living in an age of IoT, with almost everything in our daily lives connected to the Internet. According to International Data Corporation (IDC), the international IoT market is expected to grow exponentially in value, from USD 655.8 billion in 2014 to over USD 1.7 trillion by 2020. McKinsey has predicted that the progress of the IoT will exert a huge ripple effect on production, as manufacturers start adopting IoT applications for optimizing processes, forecasting, and inventory management, thereby generating additional economic value of anywhere between USD 1.2 trillion to USD 3.7 trillion a year.

Supply- and demand-side factors will drive this explosive IoT market growth. On the supply side, we can observe the advancement of ICT and inter-industry convergence. The advancements of communications technology and infrastructure has made it easier than ever to connect people and their devices. As cloud computing and big data have become daily norms and the prices of electronics and smart devices have continued to drop, the IoT ecosystem has expanded dramatically. On the demand side, the IoT is expected to offer scientific and technological solutions for a number of serious social problems. The number of single-person households, environmental pollution, and various urban problems are all expected to increase. We can solve these problems by applying smart technology to almost all human activities in relation to energy, environmental preservation, construction, and transportation. The IoT, in particular, is expected to dramatically increase the demand for mobile medical devices that can provide self-diagnostics and remote treatment given the world's aging populations.

The IoT, when incorporated into manufacturing, can help minimize costs and maximize productivity simultaneously. Connecting diverse machines and systems in production facilities will enable information exchange, leading to greater automation of production systems and minimizing the need for human intervention. The IoT, furthermore, can help optimize the energy consumption of factories and proactively troubleshoot errors in production systems via networks of detectors and wireless communications. Germans anticipate that the IoT will usher in the "Fourth Industrial Revolution" or "Industry 4.0" when applied to manufacturing. In the coming years, the IoT is likely to motivate sweeping changes across industries and open up a host of new business opportunities in conjunction with cloud computing and big data.

Companies in advanced economies primarily adopt new technologies to enhance cost-effectiveness and efficiency. The IoT, however, can achieve so much more by creating opportunities for new services and solutions to social problems. Connecting medical equipment at a hospital, for example, can prevent misdiagnoses, delays in medical care, and help to diversify and personalize patient services. By changing the ways in which public services are delivered, the IoT can significantly improve the quality of life for citizens. It is anticipated that the IoT will also transform the way we work. Contrary to pessimists, the digitalization of human labor will likely create new jobs. With the IoT applied across industries, humans will no longer compete with machines, but rather cooperate with machines to increase productivity. This human-centered automation will, in turn, enable humans to focus more on creative and innovative activities for boosting productivity. The dissolution of barriers among industries will give rise to new hybrid industries, such as digital pharmaceuticals, precision agriculture, and smart manufacturing, which will also create new jobs. In particular, demand will grow for specialists with knowledge and skillsets that cannot be automated, including software development, big data analysis, and system integration and security.

The IoT will revolutionize modes of production as well, shifting the emphasis from mass-production of limited varieties to a vertical value chain producing small quantities of many varieties. Businesses will be compelled to switch to more innovative production systems as a result. A major factor prompting this shift in production is the emergence of 3D printer technology and related software that enable almost anyone to produce prototypes of their ideas. Businesses will therefore need to pioneer new products and services by applying the IoT to their core capabilities.

4. Growth Potential Evaluation and Policy Demand Analysis

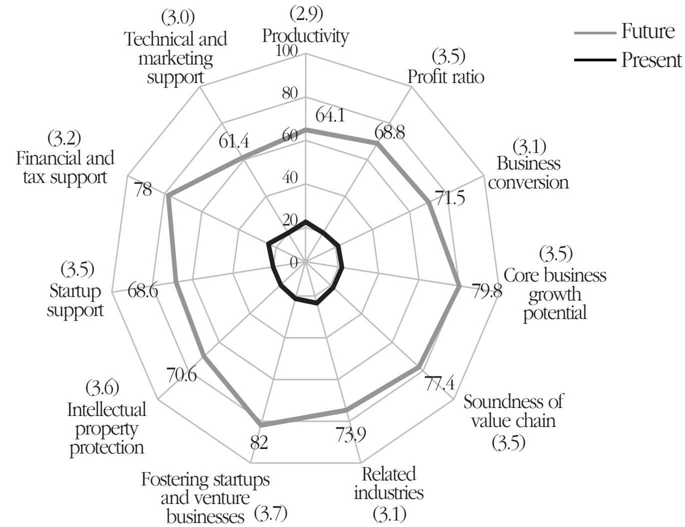
□ Opinion poll on the innovative capabilities and future preparedness of businesses

We conducted an opinion poll on the members of 150 to 200 businesses in each of the four analyzed industries. Of the 716 copies of the questionnaire returned to us, we excluded those with omitted answers or answered by businesses hiring fewer than five people (except in the IT service industry). A resulting total of 574 samples were used in our statistical analysis.

The majority of polltakers answered that their companies had not yet produced innovative achievements, having neither developed innovative products/technologies nor made innovative improvements to existing products/technologies in the last three years. However, 20.9 percent of the surveyed businesses had developed at least three or more innovative products each, and another 18.6 percent had developed one or two such products each. In other words, product innovation seemed more prevalent than process or business innovation. As for investment in intangible assets, 56.6 percent of the businesses invested less than four percent; 15.3 percent, four to seven percent; and another 15 percent, 13.1 percent.

When asked to rate the soundness of their surrounding industrial ecosystems, polltakers generally deemed them to be normal. However, they expected that the importance of industrial ecosystems would increase significantly over the next decade, from an

Figure 2. Changing Relative Importance of Industrial Ecosystems: Present and Future

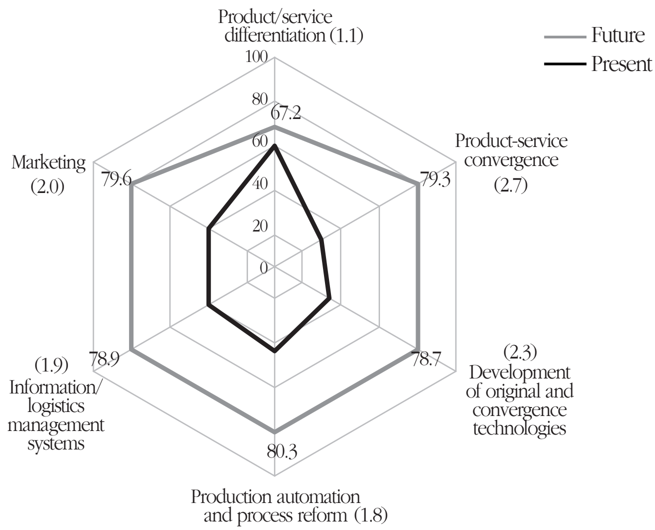


Note : Figures without parentheses represent the sums of scores, out of a five-point scale, given by polltakers who rated industrial ecosystems as "important" or "very important." Figures in parentheses represent the relative changes in the importance of industrial ecosystems, i.e., future importance/current soundness.

average of 3.7 to 4.0 points (out of a five-point scale). In particular, polltakers answered that the relative importance of industrial ecosystems would increase dramatically with respect to fostering startups and venture businesses (3.7 times up), the protection of intellectual property rights (3.58 times up), the soundness of the value chain (3.5 times up), and support for startups and venture capital (3.48 times up).

Polltakers were also asked to rate their current level of innovation in various categories of business activities. The highest-rated category, with an affirmation rate of 31 percent, was marketing, followed almost equally by business model innovation (29.8 per-

Figure 3. Current Levels of Innovative Capabilities and Future Importance



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cent) and organizational innovation (29.4 percent). When asked to rate the innovative capabilities of their businesses, polltakers rated the capabilities for product/service differentiation and production automation relatively highly, but rated the capabilities for product-service convergence and the development of original and convergence technologies relatively poorly. In the meantime, the majority of polltakers forecast that the importance of innovative capabilities in almost all activities would grow significantly over the next 10 years, especially with respect to production automation and process reform, product-service convergence, and information and logistics management systems.

□ Industrial competitiveness and policy support

Polltakers picked the United States as the leader of the four future manufacturing industries, except for smart cars. However, the United States was expected to catch up with Germany, the current leader of the smart car industry, in a decade's time, while maintaining its dominance in the other three industries, i.e., convergence materials, biomedical services, and IoT and IT convergence. The United States' leadership will remain particularly strong in the IoT and IT convergence industry, while Germany and Japan are expected to see their competitiveness decline in the three industries over the next decade. By contrast, China's competitiveness will grow in all industries to an extent of threatening Korea in the smart car, convergence materials, and biomedical service industries.

We compared the relative competitiveness of Korea, China, and Japan (with the United States' competitiveness equaling 100). Korea currently lags behind Japan in all the four industries but is expected to close the gap in 10 years. China lags far behind both Korea and Japan but will likely improve its competitiveness in all four industries, threatening both Korea's and Japan's smart car industries.

When asked what types of policy support they would need to develop the four future manufacturing industries, polltakers named infrastructure, early R&D support, and policy funding. While polltakers generally agreed with the need for more distinct policy support for innovative and future-oriented industries, the preferred types and functions of policy support differed from industry to industry. Overall, support for the creation of early markets garnered the highest score (4.4 out of 5), indicating that the more innovative an industry, the higher the barrier to market entry. Another high-scoring policy support measure was preferential financial support (4.2 out of 5).

□ Empirical analyses of factors for innovation and policy support

① Factors affecting the prospects for innovation

We ran an empirical analysis of the opinion poll results to identify the factors affecting product, process, and business model innovation, along with how innovation capabilities differed by business type and industry. We also analyzed how the types of preferred policy support differed according to the characteristics of businesses, industries, and innovation involved. Supporting our empirical analysis were a probit model and an ordered probit model, based upon the theories of dynamic capabilities and industrial ecosystems.

Our probit analysis revealed that business size, export performance, investment in intangible assets, and collaboration with outside parties all bore one-percent significance as factors possibly affecting product innovation. With regard to policy support, businesses experienced with policy projects that support funding and marketing, R&D, and new growth engines tended to produce more innovative products than businesses without such experience. For the capability to adapt to future changes, the ability to recognize and adapt to changes in the market environment had a one-percent significance. In other words, the more a business can adapt to the changing tastes and needs of consumers, changes in global trends, shorter innovation lifecycles, and growing competition, the more capable it is of developing innovative products.

Decisive factors affecting process innovation included business size, export performance, investment in intangible assets, and collaboration with outside parties—all of which coincide with the factors of product innovation. In other words, factors such as sales revenue, exports, intangible assets, and collaboration with outside parties exert a positive impact on almost all innovative activities. With respect to policy support, experiences with policy projects and new growth engine projects emerged as factors with a five-percent significance, while experience with government R&D projects had a significance of 10 percent.

Factors that led to the introduction of innovative business models coincided with the factors of product and process innovation. With respect to policy support, experience with policy projects emerged as a factor with a 10-percent significance. Where the expandability of networks was concerned, the openness of organizational culture emerged as significant, while productivity also showed strong correlation. Productivity was an important factor in business model innovation, just as it was in process innovation, most likely because productivity and profitability are chief criteria for innovation in the conventional model of catch-up growth. In terms of adapting to future changes, the ability to catch new business opportunities showed a significance of five percent.

② Factors determining perceptions of the importance of innovative activities

When we explored what made a difference to the perception of the importance of product innovation, we discovered, first, that the smaller the business' revenue, the more active its technological partnerships and transactions; and the stronger its productivity and profitability, the more importantly the business viewed product innovation. As far as the pace of change in industrial environments was concerned, the level of competition on the market and the pace of technological change emerged as factors with a five-percent significance. In terms of innovative capabilities, production automation and process reform showed a one-percent significance, while marketing capabilities showed five percent. In other words, businesses are increasingly recognizing that activities supporting product innovation are important in anticipation of intensifying competition and the increasing pace of technological change.

Second, in terms of process innovation, the greater the business' experience with future projects, the more open its organizational culture; and the stronger the productivity and profitability of the surrounding ecosystem, the greater the perceived importance of process innovation. In terms of the pace of change in industrial environments, the level of competition on the market and the pace of technological change showed a significance greater than five percent. In other words, the more intense the competition and faster the technological change, the more importantly businesses viewed activities supporting process innovation. In terms of innovative capabilities, production automation and process reform showed a significance of 10 percent in the positive direction, and marketing capabilities showed likewise in the negative direction, as in the case of process innovation.

Third, factors that significantly affected the perceived importance of business model innovation included the openness of organizational culture, the state of the business infrastructure, the level of competition in the market, and the pace of technological change. In terms of innovative capabilities, the ability to differentiate products and services showed a one-percent significance in the negative direction, and production automation and process reform showed likewise in the positive direction.

When we used industry dummy variables, we discovered that businesses in the smart car industry assigned greater perceived importance to product innovation than did those in the IoT and IT convergence industry. However, no such distinction emerged among industries with respect to the perceived importance of process innovation. As for business model innovation, smart car businesses assigned greater perceived importance than those in the biomedical service industry.

③ Factors determining the perceived need for policy support

Our analysis of the factors that shape and determine businesses' need for policy support as part of their future preparations revealed that diverse policy measures are going to be crucial. Business sizes and the extent of their technological collaborations showed an inverse correlation to a need for policy funds. In other words, the smaller a business and the less active its technological collaboration, the greater its need for policy funds. The soundness of industrial ecosystems and the level of competition on the market also emerged as factors, with a one-percent significance.

With regard to innovative capabilities, the capacity for product-serve convergence showed 10-percent significance. Positively correlating with the need for R&D policy support measures were the openness of organizational culture, the level of market competition, the pace of technological change, production automation and process reform, and information and logistics management systems. On the other hand, the productivity of the industrial ecosystem, the capability for developing original and convergence technologies, and marketing capabilities showed negative correlations.

The more open a business' organizational culture, the more intense its competitiveness on the market; the faster its pace of technological change, the more capable of production automation and process reform; and the better its systems for managing information and logistics, the greater importance it assigned to policy support projects. On the other hand, businesses facing under-productive industrial ecosystems and lagging behind others in terms of their capacity for developing original and convergence technologies also showed eagerness to make use of policy projects to enhance their innovative capabilities. Our analysis of industry dummy variables showed significant gaps among the smart car, IoT, and biomedical service industries with respect to their policy support needs. The convergence materials industry emerged as distinctive with respect to policy funds only.

④ Factors affecting the need for policy projects tailored to new growth engine industries

It is crucial to identify and foster so-called "new growth engine industries" to prepare for the nation's future. We thus examined and analyzed the factors that affect the perceived need for policy support specifically catering to new growth industries in their nascent stage.

First, businesses' ratio of investment in R&D showed an inverse correlation of five-percent significance to tax support and support for human resources development. Experience with future-oriented industry projects also showed significant inverse correlations to support for R&D, tax support, and support for human resources development. The fact that these indicators of internal innovation bear negative correlations to policy support indicates that smaller businesses without an export history are in greater need of policy programs catering to new growth engine industries.

Policy support for R&D and financial aid bore correlations of one-percent significance to network expandability and experience with technological collaboration. This finding indicates that businesses need R&D-specialized and customized financial support that facilitate diverse types of technological collaboration. With regard to ecosystem soundness, the more advanced a given business infrastructure, the greater the need for tax support; and the sounder the industrial ecosystem, the greater the need for human resource development support and early market formation support.

Regarding the pace of changes in industrial environments, the level of competition on the market bore strong correlations to policy support for R&D, financing, human resources development, and early market formation. The pace of technological change also showed correlations of five-percent significance to policy support for R&D, taxes, finance, and human resources development. These findings suggest that businesses in new growth engine industries will require policy support to enhance their adaptability to increasing competition and technological progress ushered in by the shifting industrial paradigm.

5. Prospects and Industrial Ripple Effects of Smart Cars and Convergence Materials

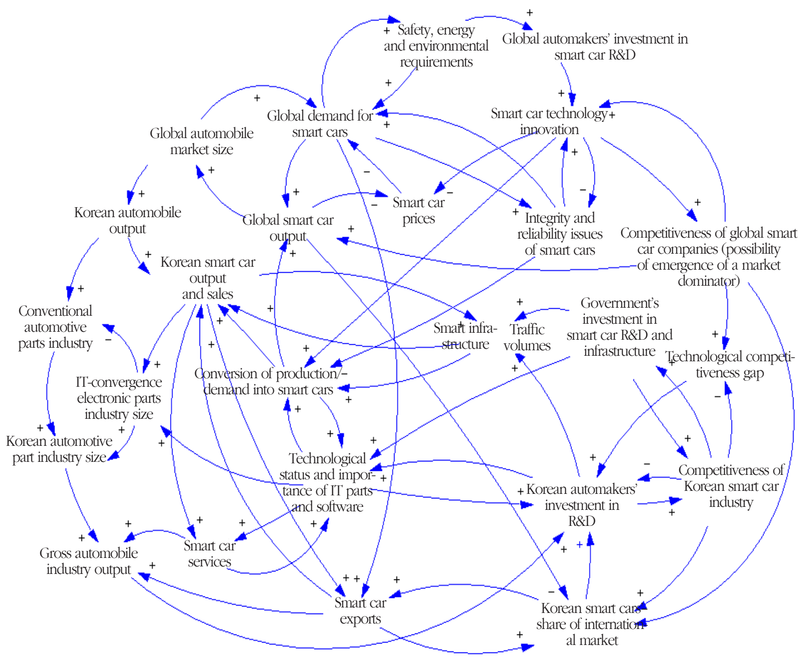
We forecast the long-term prospects and analyzed the ripple effects of the growth of the smart car and convergence material industries using a system dynamics model. System dynamics analysis provides a useful tool for projecting the trajectory and tasks of the future growth of industries if there is a dearth of quantitative data.

□ System dynamics analysis of smart cars

The growth of the smart car industry will be subject to a dynamicity and complexity of factors, as shown in the chart below. The chart presents the causal relations between the global demand for smart cars and technological innovation, between the growth of the Korean smart car industry and its competitiveness, and between the competitiveness of Korean smart cars on overseas markets and their export prospects.

We can create a simulation model using the variables identified on the causal relation map and employ that model to forecast the growth and ripple effects of the smart car industry. Based upon our basic simulation model, we predict that the international automobile market will grow to produce 150 million cars by 2030, 64

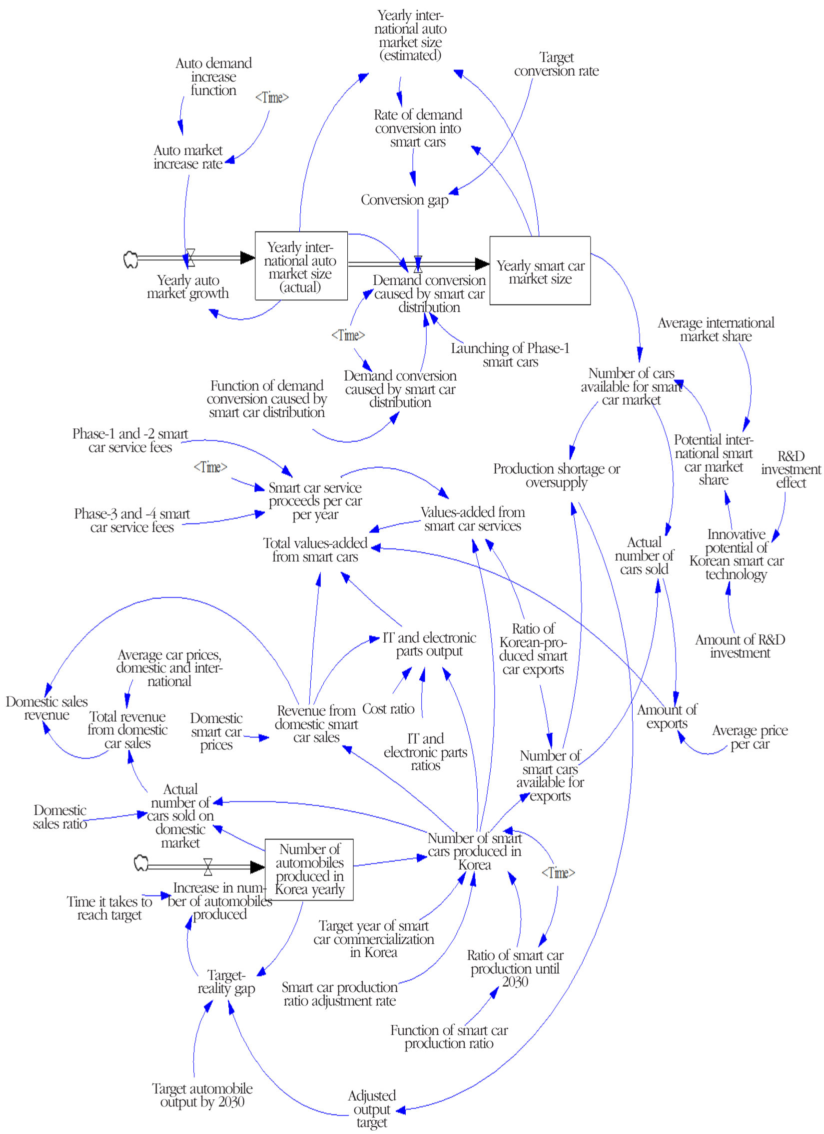
Figure 4. Causal Relations of the Dynamic and Complex Factors of the Smart Car Industry



million of which will be smart cars. Our model shows that the Korean automobile industry will produce 11.43 million cars by 2030. The production of smart cars will not begin until circa 2018, with an initial 350,000 cars, but will grow to a total of 5.77 million smart cars, taking up almost 50 percent of the total auto output by 2030.

Our basic simulation model forecasts that the total values-added from smart cars will amount to KRW 80 trillion a year by 2030. Domestic sales of smart cars alone will generate an additional KRW 20.2 trillion in values-added. IoT-converged and electronic parts will amount to KRW 41.9 trillion in output, and smart-car-related

Figure 5. Simulation Model for the Growth of the Smart Car Industry

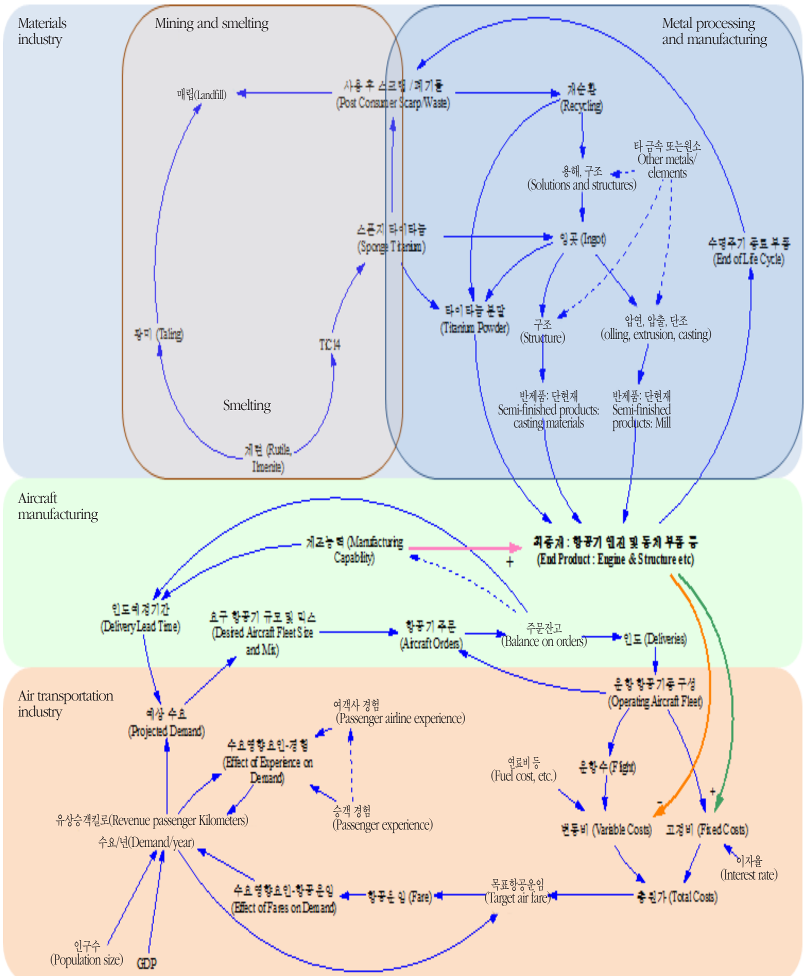


network and content services will generate another KRW 3.1 trillion in values-added.

Our simulation of the future of the smart car industry predicts that at least half of all automobiles produced worldwide will be smart cars by 2030, and that smart cars will make up around half of all automobiles produced in Korea as well. The smart car industry will thus exert far-reaching ripple effects on other industries and the national economy as a whole. Autopilot and other smart cars are intelligent products that require the convergence of almost all available technologies. In transforming overall market structures, they are likely to determine the future course of the competitiveness of national economies. Our simulation analysis indicates that to create a massive, innovative, and dynamic smart car ecosystem, Korea needs not only automakers, but also the Korean government to actively foster and promote the smart car industry, facilitate the development and collaboration of IoT and automobile technologies, expand smart car industry infrastructure, and encourage entrepreneurship and innovation.

□ System dynamics analysis on convergence materials

We applied our system dynamics model for convergence materials to the creation of a map of causal relations between the aviation industry—a major upstream industry—and the structural titanium and metallic materials industries.



The titanium industry forms relationships with both the aircraft manufacturing industry and the transportation service industry. This is because airline companies as end users decide the specifications of private aircraft, not manufacturers. But if aircraft manufacturers achieve technological innovation and improved production using cutting-edge convergence materials, including titanium, they can boost demand. Airline companies must consider the fixed cost of purchasing new and better aircraft together with variable operating costs. However, while using cutting-edge materials increases the airlines' fixed cost because of higher manufacturing costs, it reduces variable costs associated with operation and maintenance by reducing the weight of aircraft and improving fuel efficiency. The popularity of titanium, in other words, can both raise and reduce the cost to airlines. The relative importance of these cost considerations is, in turn, related to other externalities, such as fuel costs and the interest rate.

Also note the severe delays that arise at major loops in our map of causal relations and feedback. These delays may amplify the heights of business cycles. Other major factors that affect the production of convergence materials, as discernible from the above map, can be summarized as follows.

Main variable	Influence	Surrounding conditions
Demand for new aircraft	●	Rise in demand for tourism and logistics, cost of fuels
Interest rate	◎	Stability of financial institutions
Market and industrial dynamics forecasts	◎	Integrated R&D and commercialization policy
Capability for producing aircraft	◎	Parts suppliers and infrastructure at home and abroad
Primary processing technology (alloy design, casting, extruding, etc.)	●	Investment in innovative R&D, certification and standardization infrastructure
Titanium reduction/recycling technology	○	Innovative R&D support (processes)

Note : Strength of influence : ● > ◎ > ○.

6. Strategy for the Future Development of Manufacturing

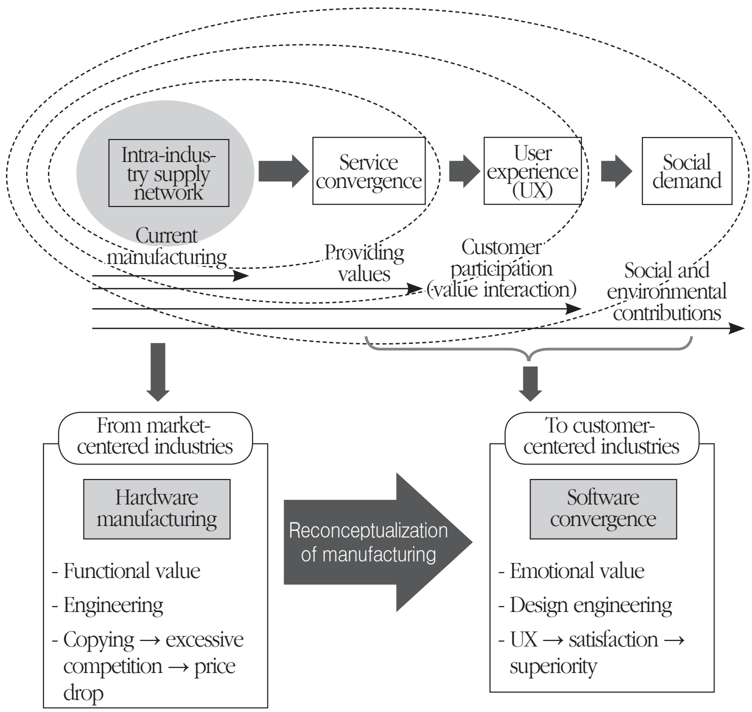
□ Preparations for a hyper-connected society

In preparing for the future, we must keep in mind that the industrial environment will change at an unprecedented pace, and that our ability to adapt will largely determine the competitiveness and capabilities of our industries. Our study forecasts that the pace of change in the industrial environment, which is already astoundingly fast, will accelerate in the future. The market will also become more unpredictable because of changing consumer tastes regarding product features and functions, the advancement of product and service technologies, and the growing uncertainty over new technologies used to create or improve products. Product-related service requirements and demand for product-service convergence will likewise change at an increasing pace.

It is therefore critical for businesses in prospective and future-oriented industries to develop and hone their ability to predict and adapt to changes in the industrial environment. In particular, they need to cultivate the capacity to recognize and manage changes in the market environment, to seize upon new business opportunities, to develop and transform internal resources and capabilities, and to rearrange their organizational structures and technologies to maximize the efficiency of internal resources.

Given the industrial paradigm shift and the likely future developments that will accompany it in the manufacturing sector, Korean manufacturers especially will need to hone their ability to cope proactively with anticipated changes in trends and to reconceptual-

Figure 6. Reconceptualization of Manufacturing in Korea



ize the role and function of manufacturing in general.

□ Strategic future positioning of industries

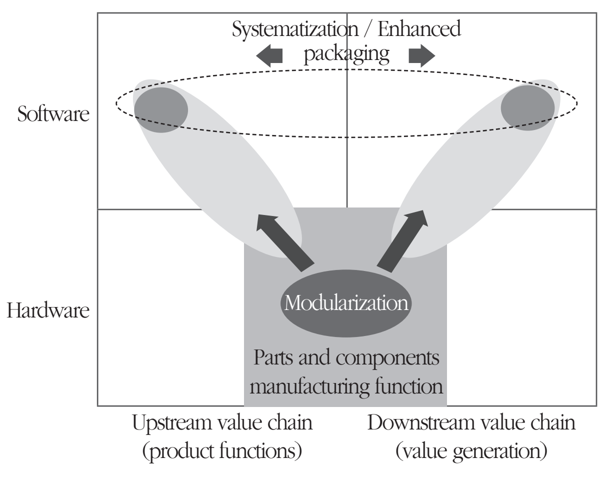
Now we need to identify the ideal trajectory of growth for the four analyzed industries based on our forecasts concerning smart manufacturing, changes in growth factors, and changes in the technological capabilities of the industries. The course of growth we decide for these industries—whether toward becoming a global market leader or seizing niche markets—will represent the starting point for important future strategies.

Preparations for a hyper-connected society should begin first and foremost with moving the current value curve of the industrial growth trajectory to a secondary value curve, thereby opening up opportunities for the four industries to leap forward. Second, we need to brace ourselves for a possible major change in the formula for industrial growth. Production efficiency, mechanical technology, and quality have been the guiding values for machinery industries such as the automobile industry up until now. A decade from now, however, the competitiveness of these industries will depend on innovation (toward greater safety and network connectivity), convenience, design, and eco-friendliness. Production efficiency, generic technology, and functionality have led the growth of the material industry (except for the chemical industry) up until now. In the future, however, the new formula for this industry's growth will be based upon the small-scale production of multiple varieties of products, technological distinctiveness, specialization, and innovative solutions. Third, our analysis of the opinion poll and the KIET evaluation of the technological innovations and industrialization capabilities of the four industries reveal the greatest future prospects through strategic positioning for the IoT, followed by smart cars, biomedical services, and convergence materials.

Figure 7 shows the future positioning map of the manufacturing sector based upon our forecasts for its growth path, changes in growth formula, and changes in the technological innovations and industrial capabilities of the four industries. We see a number of transitions in the map: (1) a shift of focus from hardware to software; (2) the enhancement of the innovation capabilities of both the upstream and downstream industries of the value chain, and the strengthening of the systemic functions for linking the two streams; and (3) the shift of emphasis from production (functional value) to value generation, and from disparate products and industries to integrated products and industries.

In sum, the successful future of the manufacturing sector lies in transitioning to a softer and convergence-centered sector, with a greater capacity for systemically integrating manufacturing, services, and infrastructure. More specifically, the central emphasis will need to shift from parts and components to integrative modularization, with software playing a more decisive role in the upstream industries (in terms of planning, design, and engineering) and a greater focus on customer satisfaction and service in the downstream industries.

Figure 7. Strategic Future Positioning of the Manufacturing Sector



□ Future strategy for the manufacturing sector

For the prospective manufacturing industries and the manufacturing sector as a whole to translate their innovative capabilities into greater competitiveness, they need to adopt a new strategic paradigm. The following table summarizes the policy and strategic measures that are required for the manufacturing sector to achieve its ideal future position in 10 years.

	Strategy
Increasing capability for industrial systematization	- Systematization for expanding service convergence - Increasing values-added through long-term systematization: introducing systemic convergence into not only manufacturing, but also environmental protection, energy, solutions for the aging population, and other social issues
Establishing investment strategies to satisfy future demand	- Strengthening innovation strategies based on long-term demand forecasts for a hyper-connected society - Making a shift from manufacturing- and development-centered capabilities to open innovation capabilities, and adopting value- and convergence-centered investment strategies for creating new future business opportunities - Developing and adopting technologies that add distinctiveness and customer values to the existing system of manufacturing
Ensuring a harmony of the catch-up strategy and the leading strategy on technology development	- Managing the existing catch-up strategy effectively, while also adopting creative strategies for innovation - Establishing a centralized organization to support demand-based strategies for technological innovation - Undertaking both short- and long-term R&D projects - Using creative, leading strategies with respect to industrial-academic collaboration, and using catch-up strategies to create convergence products
Strengthening intellectual property management strategies for small and medium enterprises (SMEs)	- Instituting policy and legal means to help SMEs with disputes over intellectual property rights and to encourage them to innovate - Strengthening the intellectual property ecosystem - Using strategies of pursuing intellectual property rights (including patents) from the beginning of the R&D process onward
Promoting open innovation for improving dynamic capabilities	- Establishing an environment of fostering open innovation in SMEs - Encouraging large corporations and SMEs to share innovation models - Developing and distributing new models of industrial-academic collaboration: encouraging companies to host university research centers - Real option strategy: encouraging investment in startups with prospective technologies - Providing greater policy support for technology sponge and broker strategies

Table 1. Types of Open Innovation and Related Activities

Types of open innovation	Innovative activities		
	Product innovation	Process innovation	Business model innovation
Technology-only type	- Strengthening internal resources and capabilities	- Developing Nano technologies - Developing energy-saving IT	- Using big data
Technology-fountain type		- Automating production - Developing energy-saving IT - Developing/acquiring core technologies	- Developing contents - Using big data - Developing convergence platforms
Technology-sponge type	- Developing new products - Developing intelligent products - Securing core patents - Developing spinoffs - Launching R&D collaboration	- Making products lighter - Developing/acquiring original micro-precise technologies - Developing thermal, super-durable, and other convergence materials - Commissioning research	- Adopting informatization technologies - Developing package-type solutions - Employing crowd and customer participation systems - Developing personalized contents
Technology-broker type	- Emotional designs - Developing new products - Developing intelligent products - Acquiring core patents - Developing human interface technology	- Developing energy-saving IT - Developing next-generation technologies - Creating smart factories/work systems - Automating production	- Developing product convergence solutions - Developing service convergence models - Establishing distinctive ecosystems/value chains

We also conducted an additional expert survey among the industry experts at KIET and a small number of outside specialists to identify and prioritize policy tasks as strategies in response to the new industrial paradigm. We identified and prioritized national and social issues, global trends, and future manufacturing issues forecast by international market research agencies that are likely to exert a major impact on industries.

Table 2. Prioritizing Policy Tasks Required to Prepare for the Future

	All manufacturing	Smart cars	Convergence materials	Biomedical services	IoT and IT convergence
1	Developing original technologies	Developing original technologies	Supporting development of original technologies	Supporting development of original technologies	Supporting development of original technologies
2	Fostering convergence-oriented human resources	Fostering convergence-oriented human resources	Fostering convergence-oriented human resources	Supporting development of Korean-style new growth engines	Fostering convergence-oriented human resources
3	Supporting development of Korean-style new growth engines	Supporting development of Korean-style new growth engines	Facilitating entry into and exit from the market	Strengthening future forecast-ing capability	Supporting development of Korean-style new growth engines
4	Strengthening future forecast-ing capability	Facilitating entry into and exit from the market	Strengthening digital manufac-turing capability	Promoting servitization of manufacturing	Strengthening future forecast-ing capability
5	Strengthening digital manufac-turing capability	Strengthening digital manufac-turing capability	Supporting development of Korean-style new growth engines	Strengthening digital manufac-turing capability	Financial and tax reforms to support new industries
6	Facilitating entry into and exit from the market	Strengthening industrial ecosystem infrastructure	Improving busi-ness environ-ment for SMEs	Fostering convergence-oriented human resources	Strengthening industrial ecosystem infrastructure
7	Strengthening digital manufac-turing capability	Strengthening digital manufac-turing capability	Strengthening digital manufac-turing capability	Improving busi-ness environ-ment for SMEs	Improving busi-ness environ-ment for SMEs

□ Future development strategies for the four industries

① Smart cars

Increasing IT convergence will enable the auto industry to continue generating values-added and creating new jobs through the development of new products and features. As the scope of suppliers in the auto industry expands to include even non-automakers, it will be critical for businesses in the industry to adopt open innovation structures. This will involve improving the structure of the existing automotive parts industry and making it easier for new businesses to enter the auto industry ecosystem. The auto industry also needs to adopt an open innovation structure with strategies that promote research collaboration, technological partnership, and other win-win activities. Automakers and the enlarged scope of parts suppliers need to identify respective strategic areas of activities, and distinguish between projects in need of collaboration and others in need of competition toward achieving the common goals of lowering the cost, enhancing the performance, and strengthening quality.

Policymakers will need to support horizontal R&D collaboration between large corporations and SMEs, while also enhancing the innovative capabilities of the latter through technological partnerships and the like. The emergence of smart cars will open up new fields upon which SMEs can grow. The government thus needs to establish a constantly growing and expanding industrial ecosystem.

② Convergence materials

The materials industry encompasses a wide variety of subfields. It is therefore impossible to establish a single common development strategy for all of its diverse businesses and subfields. However, based upon forecasts regarding changes in trends and the opinion poll results, we can summarize the future positioning strategy for the material industry as follows.

	Present	Policy objectives	Future
		Convergence materials	
On the supply side	· Mass-production of limited varieties · Technological leadership (market size) · Generic, all-purpose technology · Centered on individual large corporations · Capital- and labor-intensive · Simple value chain · Focused on minimizing cost and speeding up production · Vertical integration (R&D – production – distribution) · Competition with China and Japan	1. Increasing labor productivity (with smart factories) 2. Strengthening marketing capability (support for globalization) 3. Product differentiation (providing technology, product and industry information, and forecasts) 4. Managing competition with neighboring countries (providing information and policy guides on Chinese regulations) 5. Manufacturing-service convergence (engineering services and others) 6. Promoting and supporting demand 7. Supporting development of both cutting-edge and all-purpose technologies	· Small production of large varieties · Technological leadership (market portfolio) · Specialized technology · Greater equity among businesses and industries · Knowledge-intensive · Complex value chain · Greater values-added and reliability · Horizontal integration (product-service convergence) · Cooperation with China and Japan
		Policy	
On the demand side	· Focus on function · Improving existing function · Focus on price · High customer loyalty · Preference for domestic procurement	8. Supporting development of original technologies 9. Supporting human resource development (a two-tier strategy involving both on-site production workforce and future-pioneering research workforce)	· Focus on performance · Creating new functions · Demand for packages and solutions · Diversifying demand · Global procurement

	Present	Future
Examples	· Steel and related materials · Construction, railroads, shipbuilding, and automobiles · Low-value-added mass-production	· Extreme materials (metals and non-metals) - High-specific strength materials: high-tensile strength steel (TRIP, TWIP, CP, etc.) - High-specific strength non-ferrous metals: Al, Mg alloys, etc. - Non-ferrous materials with high specific strength, heatproof and rustproof features: Ti alloys, etc. - Carbon fiber reinforced plastics (CFRP), etc. · Aircraft, automobiles, biomaterials, etc.

③ Biomedical services

As the center of gravity of the future healthcare system shifts to diagnostics, prevention, and management, the demand for smart and convergence-based biomedical services will grow at an explosive pace. It is therefore critical for Korean healthcare businesses to utilize the nation's strong IT resources to enhance their competitiveness and actively pioneer new markets abroad. The Korean government also needs to reform regulatory structures to foster convergence-oriented R&D and strengthen supply capabilities, and it should launch consumer awareness campaigns to increase the demand.

Most importantly, new incentives and more efficient policies and regulations should be introduced to better coordinate the relations among stakeholders making up the ecosystem of the biomedical service industry. Policymakers need to arrive at a fairer and more efficient system of incentives that benefit doctors, telecommunication companies, insurance companies, and the general public. These should then be introduced into new laws on medical care and insurance benefits, with the goal of increasing these stakeholders' active participation in the improvement of the industrial ecosystem. Such incentives will be essential for establishing a more cost-effective healthcare system and fostering the biomedical service industry in this day and age of population aging.

The Korean government also needs to expand the big data infrastructure and platform for biomedical services in Korea, particularly by forming networks of cooperation with the member states of the Asia Pacific Economic Cooperation (APEC). Success of the new smart biomedical industry will depend on the amount of bio and medical data available. However, it will be difficult to achieve a desired economy of scale with data available in Korea alone. To access greater data and facilitate Korean businesses' globalization, it is important to lead the establishment of big data across East Asia, encompassing China and Japan.

④ IoT

The introduction of the IoT into production processes, products, and services, will render the distinction between the horizontal and vertical value chains as irrelevant. The increasing collaboration among businesses of diverse industries will lead to the creation of new business models and opportunities. Over the next several years, companies of diverse industries and backgrounds will increasingly work together, speeding up and promoting the convergence of technologies and industries across the Korean economy. The government needs to recognize that the IoT covers an infinitely wide field of industrial activities and accordingly avoid developing abstract future strategies. Instead, it should make more helpful and accurate assessments of the state of the IoT, prioritize required specific tasks carefully, and selectively focus on those with highest priority.