# Artificial Intelligence and the Transformation of the Automotive Sectoral Innovation System

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## Abstract

**Background:** This study examines the impact of artificial intelligence (AI) on the South Korean automotive innovation system. It analyses the transformation of production-based innovation across system elements and the broader system in which they are embedded, both increasingly shaped by AI. **Objectives:** The study addresses the lack of systematic analyses of AI's impact on the automotive business system and aims to generate strategic, policy, and theoretical insights. **Methods/Approach:** The research applies an augmented sectoral system of innovation and production (SSIP) framework, combined with Delphi analysis, expert interviews, and document analysis. **Results:** The findings indicate accelerating transformations across SSIP components in both the present and the near future. Automakers, parts suppliers, and technology suppliers, together with their AI networks, emerge as leading actors, while research institutes, universities, government agencies, institutions, and consumers lag. Intensifying interactions among SSIP constituents, AI systems, and AI-based production activities and innovations further reinforce these transformations. **Conclusions:** A holistic analysis of the AI-driven automotive SSIP shows how leading actors interactively shape system dynamics. The findings provide a basis for designing policy instruments to support slower-transforming actors and facilitate overall system transformation.

**Keywords:** artificial intelligence, automotive sector, business model innovation, organisational innovation, process innovation

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# Introduction

This research focuses on the impacts of artificial intelligence (AI) on the South Korean automotive innovation system. It examines the automotive sector's production-based innovation transformation through system elements and the overall system that embeds them, both of which are increasingly driven by AI. The research aims to address a gap in systematic studies of AI's impact on the automotive business system. It is also expected to yield comprehensive strategic, policy, and theoretical insights. Key AI technologies influencing the automotive sector include machine learning (ML) and its subset, deep learning (DL), which is based on artificial neural networks. Both algorithms autonomously learn, forecast, and adapt to input data to support a variety of functions of autonomous vehicles (AVs), including machines and robots, and their related operations and services. Generative AI (Gen AI) is also increasingly used in vehicle and part designs, supply chain and operational optimisation, and consumer personalisation (Arrieta et al., 2020; Kuutti et al., 2021; Lu et al., 2024). In literature reviews by Loureiro et al. (2021), Enholm et al. (2022), and Yang et al. (2022), specific types and functions of AI, their impacts on distinct issues, and their applications and roles in business activities have been examined. A literature review by Armenia et al. (2024) has identified a research gap in joint AI and system dynamics studies in the business literature. The review only finds a small intersection of the two subjects in the areas of marketing capabilities and business environment (e.g., Rahman et al., 2021; Campbell et al., 2022), organisational creativity (e.g., Mikalef & Gupta, 2021), and knowledge management (e.g., Sundaresan & Zhang, 2022).

Most automotive literature has also examined specific types and functions of AI and their impacts on distinct issues, cases, and functions of AVs. For example, Gupta et al. (2021) studied the impacts of AI on in-vehicle experiences, connected vehicles, automotive manufacturing, and autonomous vehicles. Antonialli et al (2022) explored the effects of AI on the automotive industry and urban mobility from the standpoint of technology, regulations (public policies), and citizens (users). The investigation of the impacts of AI on the automotive production process has so far been limited. However, a comparable study on smart factories in the automotive sector by Jerman et al. (2020) underscores the need for changes in related competencies. Lastly, Demlehner et al. (2021) evaluate 20 AI use cases in the global automotive manufacturing context. They appraise the related business value and realizability throughout the automotive process. They employ a Delphi study with 39 experts in 25 different globally scattered organisations. This research then aims to broaden previous studies. This research contributes a systemic investigation into AI's effects on the innovation-production nexus and the transformation of the entire automotive sector.

Along these lines, the research framework is based on the sectoral system of innovation and production (SSIP) concept. The SSIP delineates that when a new technology is introduced into or created within a production sector that produces a group of related products, it transmits its transformative impacts through various components of the sector. The system components are as follows. The first group embraces actors (individual and organisational agents). The second group encompasses the actors' interactive networks of relationship (market and nonmarket, communication and exchange, competition, and collaboration) occurring through the creation, learning and selection of new knowledge and technology (applied knowledge) as well as through the utilisation of them in the production of innovation (new and/or significantly improved product), the latter of which is commercialised in the market selection process to meet consumers' demand. The third group includes the embedding of formal and nonformal institutions (rules) that shape the above components (Edquist, 1997; Malerba, 2002, 2004, 2005). To better understand AI-driven transformation of the automotive production-based innovation system and to provide a theoretical contribution, the SSIP framework is extended for broader analytical application. The extended framework serves as an input to the Delphi study, expert interviews, and document analysis at the initial stage of data collection.

The framework is extended to encompass a broader range of innovations beyond traditional product innovation, as well as a wider set of production-based activities beyond conventional knowledge (technology) creation. This extension also opens the boundaries of the sectoral system under study and adds features that may generate more comprehensive insights when the framework is applied to other sectoral systems.

Following Demlehner et al. (2021), the dynamic nature of AI supports the use of expert interviews and the Delphi method as foresight-oriented approaches. These methods enable the study to examine both present and anticipated future innovation-based transformations of the automotive SSIP. In addition, document analysis is used to complement and triangulate the expert-based evidence. This mixed-method approach, combining quantitative and qualitative data sources, strengthens data completeness and enhances the overall validity of the study. The South Korean automotive sector was selected because the country has emerged as a global leader in AI technology research and development, patent applications, and active participation by firms, research institutes, and governmental authorities (De Prato et al., 2019; Righi et al., 2020). This, in part, drove South Korea to prevail as the sixth most innovative economy in the world in 2024 (WIPO, 2024). Its automotive sector has also been among the world's leaders in production and innovation dynamism. South Korea has emerged as the fifth-largest world producer of passenger cars since 2020 (Korea Automobile Manufacturers Association, 2024). Lately, its leading firms have led those of Japan, the first-ranked automotive producer in terms of production value in hydrogen and other green vehicles (Stangarone, 2021; Hatani & Lee, 2023). Accordingly, the following specific research questions for the study are posed: (i) RQ1: What are the levels of production-innovation-based transformations of the core actors and their networks in, and the institutions embedding the South Korean automotive SSIP driven by AI, at present and in the near future?; (ii) RQ2: What are the detailed dynamics of production-innovation-based transformations of the core actors and their networks in, and the institutions embedding the South Korean automotive SSIP driven by AI, at present and in the near future?

Addressing RQ1 and RQ2 enables the study to map the overall AI-driven transformation of the South Korean automotive SSIP, from the observable present to anticipated future developments, and to derive related strategic, policy, and theoretical implications. The remainder of the paper is organised as follows. Section Two explains the methodology. Section Three presents the results. Section Four discusses the theoretical, strategic, and policy implications. Section Five concludes.

# Methodology

## *The augmented SSIP framework*

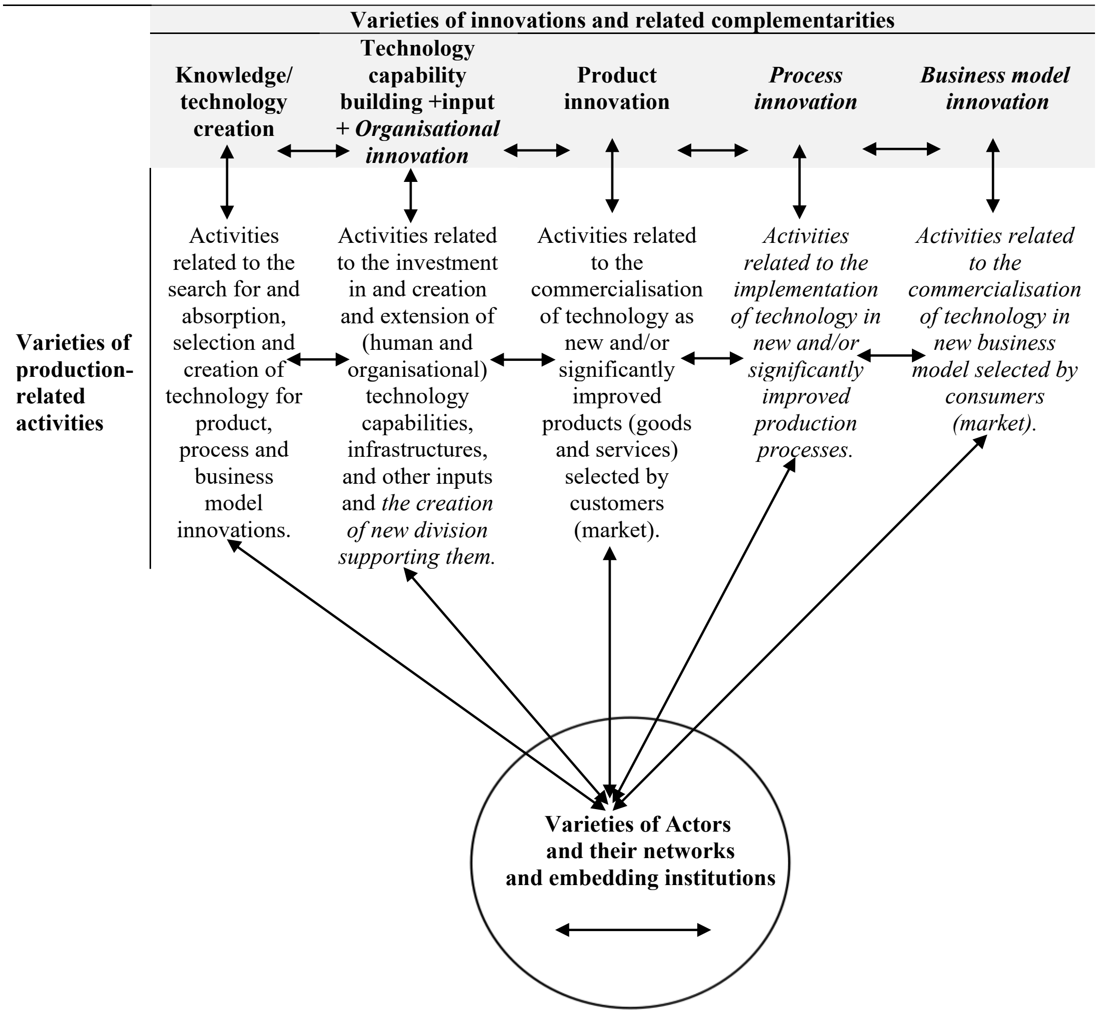
The SSIP framework is founded on a production system that propels its production process by utilising necessary inputs, mainly knowledge (technology), and learning in the (new or old) production process, to create new or significantly improved products. The new products are commercialised to meet consumer demand. Therefore, within the framework, the system is a production-based innovation system from which product innovations are derived. The framework focuses on the roles of interactive system components (actors, their interactive networks, and the institutions that shape them) in the above process. It also highlights the evolutionary processes of generations of varieties in technology, products, firms, and organisations, and the final selection of them (Nelson, 1997; Metcalfe, 1998; Malerba, 2002). There are some limitations of the traditional SSIP framework. First, it primarily concerns the creation and flow of product technologies (knowledge). This is also related to knowledge bases, competence, technology capabilities (Bell & Pavitt, 1995), infrastructures, and learning (Edquist, 1997). However, traditional SSIPs fail to explain the process of technology commercialisation as an innovation fully. Second, the innovations are usually a group of new products assumed to derive after a variety of new knowledge has been utilised and the market has selected them. A limited number of SSIP studies extend the concept to cover part of process innovations (Edquist, 1997). The framework has not yet been integrated into the concept of business model innovation (Teece, 2010; Amit & Zott, 2012). Third, the studies on production activities that yield all the above innovations have been limited. To advance the framework and improve its ability to investigate real, holistic transformations of the AI-driven automotive SSIP, a variety of existing and emerging innovation concepts beyond product innovation are integrated, and the dynamic production-based activities that generate them are explicitly accounted for. This extension moves beyond a narrow focus on technology or knowledge creation and related concepts of technological accessibility, opportunity, cumulativeness, and product innovation appropriability (Malerba, 2002, 2004, 2005). The augmented framework is illustrated in Figure 1.

In Figure 1, the SSIP is an open system. Two-way interactions among its components, denoted by two-way arrows, drive its adjustments and transformations. The dynamics of the technology-driven transformations began with a variety of actors, their networks, and embedded institutions at the bottom centre, where they could interact to generate change. They could begin system transformations by carrying out, supporting, and shaping specific production-based activities in the middle row of the figure to realise related innovations in the top row. Two-way arrows represent these interactive vertical relationships. As mentioned, more innovation concepts are added to the framework to realistically and holistically illustrate the SSIP transformations. The additions made are indicated in italics in the figure and include *organisational, process, and new business model innovations that extend across* the overall innovations. They have been developed separately but are rarely utilised within the SSIP framework, although process innovation could be readily applicable (Edquist, 1997).

Organisational and business model innovations can be developed without new technology; both can be alternatives to or complements of other technology-based innovations in augmenting value for organisations. OECD (2005) defines organisational innovation as the implementation of new organisational methods in the firm's practices, workplace organisation, or external relations. The business model innovation is here defined as a new way of designing, architecting, or conducting business to create, deliver, and capture value (Teece, 2010), within a system of interconnected activities interacting with partners, vendors, and consumers (Amit & Zott, 2012). Here, the focus is only on the technology-driven aspects of all the innovations.

There could be relationships among some of the innovations and their complementarities, as well as those among their founding production-related activities in the middle row. Therefore, horizontal two-way arrows are used to represent the probable interactive relationships among them, spanning both the top and middle rows. The new grounding production-related activities matched with the newly added innovations are also made italic in the figure and include: *the creation of a new division supporting technology capability building, activities related to the implementation of technology in new and/or significantly improved production* *processes, and activities related to the commercialisation of technology in a new business model selected by consumers (market).* After all, the framework adds, on top of the traditional SSIP framework, varieties at different levels of the system that are crucial for system transformations.

*Figure 1*
The Augmented SSIP Framework




*Source:* Author's work

## *Research design*

This study uses and triangulates Delphi analysis, expert interviews, and document analysis, together with their related data sources, to achieve data completeness and strengthen the overall validity of the study. The extended SSIP framework serves as the analytical basis for all methods at their initial stages. The bias potentially arises from a limited group of experts utilised below, which is expected to be partially remedied by the full extent of document analysis. Besides, the Delphi procedure has been continuously developed to reduce bias. Provided that the experts interviewed are also drawn from the initial Delphi process, lower bias in expert interviews is anticipated.

### *The Delphi research*

Data collection under this procedure is part of the larger Delphi survey, which collected data on innovation-based system transformation, system failure, and actor group adaptability in the automotive and broadcasting sectors. Data unrelated to this paper are to be published under a different concept and in a different industry in separate academic journals.

Following the literature and its triangulation procedure (Popper, 2008; Weber & Schaper-Rinkel, 2017), the Delphi process began by selecting an initial group of experts with diverse backgrounds to recommend a larger, well-balanced, and representative panel for the Delphi survey. This initial group included 18 experts: 5 from the Ministry of Science, Technology, and ICT (MSIT), 5 from the Ministry of Trade, Industry, and Energy, 5 from the Korean Institute of S&T Evaluation and Planning (KISTEP), and 3 from an association, a public institution, and a university. They subsequently recommended 32 experts, comprising 12 artificial intelligence specialists and 20 automotive sector experts, for this research. These experts represent diverse backgrounds across government and public agencies, research institutes, universities, and business firms, and were selected in line with the research scope, budget, and time constraints. The Delphi survey was conducted anonymously via email. In the first round, conducted from September to October 2022, 26 out of 32 experts responded. After summarising the results, a second round was conducted to share and validate the initial findings. The two-tier expert selection process, together with iterative result sharing, confirmation, and refinement across two Delphi rounds, helped reduce potential bias.

The Delphi survey was designed for quantitative appraisal of the relative transformation at present (2022) and in the next five years (2027) of the SSIP components: five actors, automaker and part supplier, AI technology supplier, university and research institute, government and public agency, and customer, the overall AI network, and the overall institution connected to AI. Each expert gave a score ranging from zero to nine for each anticipated transformation of each SSIP component.

It is assumed that a three- to five-year interval is appropriate for measuring the transformative effect of rapid technological change on a dynamic sector (Weber & Schaper-Rinkel, 2017). The South Korean automotive sector has been among the world's leaders in production and innovation dynamism. Moreover, the rapid and widespread adoption of AI is anticipated to bring about swift technological change (West & Allen, 2018; WIPO, 2019). For the quantitative analysis, the averages and standard deviations of the relative innovation-based transformations for the SSIP components were reported, initially calculated from the experts' responses. However, their interpreted (scaled from the averages) transformation levels have been emphasised.

The transformation levels shown in Table 1 are scaled using a 1.5 interval so that very detailed levels, from lower-low to upper-high, are all covered. The results from this part directly address RQ1.

*Table 1*
Scaling Detailed Level of Innovation-based Transformation

| Range of mean score | Level of innovation-based transformation |
|---|---|
| 7.6-9.0 | Upper-high |
| 6.1-7.5 | Lower-high |
| 4.6-6.0 | Upper-medium |
| 3.1-4.5 | Lower-medium |
| 1.6-3.0 | Upper-low |
| 0-1.5 | Lower-low |

*Source:* Author's work

*Expert Interviews*

Given that the above quantitative part addresses only the tendency and scale of the transformations, two complementary group expert interviews, totalling two hours, were conducted in March 2024. From those 26 experts, five interviewees with backgrounds in AI and five others with backgrounds in the automotive sector were interviewed. These interviews addressed RQ2 by allowing experts to provide open-ended accounts of the most important AI-driven innovation-based transformations they had observed and anticipated in the automotive sector. The qualitative results from this stage are presented and analysed alongside the findings from the document analysis.

*Document analysis*

Also, to improve understanding of the detailed dynamics of the transformations and to triangulate the above approaches, a complementary document analysis was conducted from March to October 2024. Data were collected from reports and websites of a cluster of South Korean automakers, including main parts suppliers, key technology suppliers, government and public agencies, research institutes, and laws and standards related to the automotive sector. The initial keywords searched in the data sources were: AI technology and automotive innovations; AI technology and AVs. Based on the initial data, further searches in the second stage for additional data from companies, agencies, institutes, and institutions operating in the sector and competing with or collaborating with those in the initial cluster were conducted. Additional keywords added and looked for in the data sources were: AI technology and connected AVs (CAVs), AI technology and robots, AI technology and platform beyond vehicles (PBVs), AI technology and autonomous taxi (robotaxi), AI technology and advanced air mobility (AAM), and AI technology and automotive process innovation. In the third stage, additional data on the SSIP components and keywords listed above, as well as general developments in AI and the automotive sector, have been collected from relevant online newspapers and periodicals, and via Google searches.

The SSIP components identified above are cited throughout the results section. Key online newspapers, periodicals and websites include: AI Business, Autonomous Vehicle International, Business Korea, Business Times, Chosun Daily, CNN, Computer Weekly, Future IoT, gnss.asia.com, igarr.com, IoT World Today, Just Auto, Korea Economic Daily, Korea Herald, Korea Joongang Daily, Korea Tech Today, Korea Times, Net manias, Reuters, and Us. Specific analyses are referenced with their corresponding data sources. The qualitative results from this part, which also directly address RQ2, are analysed alongside those from the expert interviews.

# Results

## *Transformations of South Korean automotive SSIP components*

The Delphi process finally included seven SSIP constituents, as shown in Table 2. The overall AI network encompasses AI-related networks of actors, while the overall institution includes laws, standards, and other rules. Table 2 presents the present (2022) and future (2027) average transformation levels of the SSIP components, as estimated by the 26 experts.

For 2022, the average (mean) levels of transformation of the SSIP components range from the highest, 5.68, for the automaker and part supplier, to the lowest, 3.64, for the consumer. AI technology suppliers, universities, and research institutes closely follow the automaker and its parts supplier, with average transformation levels of 5.60

and 5.40, respectively. For 2022, their appraisals fall into two groups: ones with an upper-medium level of transformation, automaker and part supplier, AI technology supplier, university and research institute, AI network, and government and public agency, and the others with a lower-medium level of transformation, institution and consumer. The transformations of all the constituents are projected to accelerate into high levels for 2027. For 2027, the average transformation levels of the SSIP components range from 8.20 for automakers and parts suppliers to 6.40 for consumers. Automakers and parts suppliers, as well as AI technology suppliers, are estimated to reach an upper-high level of transformation, with mean scores of 8.20 and 7.96, respectively. The remaining components are estimated to reach a lower-high level of transformation: universities and research institutes (7.48), AI networks (7.16), government and public agencies (7.04), institutions (6.52), and consumers (6.40).

*Table 2*
Present and Future Transformation Levels of SSIP Components

| SSIP Component | Present level of transformation (2022) | | | Future level of transformation (2027) | | |
|---|---|---|---|---|---|---|
| | Level of transformation | Mean score | Standard deviation | Level of transformation | Mean score | Standard deviation |
| Automaker and part supplier | Upper-medium | 5.68 | 1.67 | Upper-high | 8.20 | 0.82 |
| AI technology supplier | Upper-medium | 5.60 | 1.88 | Upper-high | 7.96 | 1.19 |
| University and research institute | Upper-medium | 5.40 | 1.68 | Lower-high | 7.48 | 1.18 |
| AI network | Upper-medium | 4.68 | 2.00 | Lower-high | 7.16 | 1.54 |
| Government and public agency | Upper-medium | 4.65 | 1.57 | Lower-high | 7.04 | 1.07 |
| Institution | Lower-medium | 3.88 | 1.57 | Lower-high | 6.52 | 1.59 |
| Consumer | Lower-medium | 3.64 | 1.78 | Lower-high | 6.40 | 1.58 |

*Source:* Author's work

## *Tracing the dynamics of component-system co-transformation*

In this subsection, the focus is on the overall automotive SSIP transformation. The actions and interactions of actors are traced, along with those of related networks and institutions, through interactive flows that link organisational innovation and human and organisational technology capability building to technology creation and to product, process, and business model innovations and their underlying production-based activities.

### *Organisational innovation and human and organisational technology capability building*

From their websites, most South Korean *automakers, parts suppliers and technology suppliers* began AI-related human and organisational capability building in the early 2010s, partly influenced by AI symposia and labs provided to businesses by Korean *universities* (see also Zhang, 2016). Their locus of AI technology capability and resources has shifted to AVs after the Ministry of Land, Infrastructure and Transport (MOLIT) issued permits for AV testing in 2016 and set up K-City and transportation and information and communication technology (ICT) infrastructures for testing in 2017. Samsung, KT, and SK Telecom (SKT), which are transforming from the electronics and ICT sectors, and companies in the Hyundai automotive group have participated in infrastructure development in the K-City and other AV testing areas. MOLIT, *the Korea Transport Safety Authority (KOTSA), the Korea Automotive Testing and Research Institute (KATRI), and several local and related government agencies* have also undertaken organisational innovations and/or transformations to support these developments. I*nstitutions*, such as the *Act on Promotion and Support of Commercialisation of Autonomous Vehicles (APSCAV)*, were more slowly enforced in 2020.

The above companies and their following counterparts have rapidly augmented their technology capabilities since the late 2010s. These include organisational innovations such as creating numerous new divisions and investing in and partnering with many foreign firms as a basis for future research. The researchers have been working on AV-related technologies, components, and AVs, and have been testing and commercialising them in specific areas in South Korea and abroad. As exemplified on their web portals, Hyundai Mobis, a parts supplier, invested in StradVision, a Korean startup, to strengthen its capability to develop deep-learning-based camera sensors. Samsung acquired Harman, a U.S. company, in 2017 to secure Harman's capabilities in audio and car infotainment. LG—also transforming from the electronics and ICT sector—has well illustrated these typical transformations: It has continuously partnered with Qualcomm, a chipmaker, with HELLA, an advanced driver assistance system (ADAS) developer and with Here, a leader in global digital mapping. Lately, Hyundai and its subsidiary, Kia, have partnered with KT and SKT, respectively, to strengthen their technology capabilities for developing CAVs. *Experts grounded in AI explain that these intensified and multifaceted transformations have arisen because automotive-related AI technologies remain underdeveloped; investing in and partnering with those who have been building particular technology capabilities helps accelerate subsequent technological developments and commercialisations.*

*Technology creation*

Built on technology capability-building activities, the above transformers have continued to scale up R&D investments in AI-based technology development. *Many experts highlight the intricacies and redundancies in technology development among automakers, parts suppliers, and technology suppliers, even within the same company group.*

From company reports and websites, they have, besides developing technologies connected to their traditional goods and services, transformed to compete by developing ML, DL, and Gen AI technologies, prototypes, and patents for product, process, and new business model innovations. They have also undertaken testing of AVs, CAVs, robots, PBVs, and/or robotaxi and logistics services, including their components and subsystems. Importantly, all these actors must conduct research and testing on ML-based autonomous driving systems, whether they are automakers, parts suppliers, or technology suppliers, and whether they utilise cars, vans, buses, or trucks as bases for developing the systems. Their technology can be used for new whole vehicles, parts, platforms, software, services, market models, or combinations of them. From their web portals, companies in the Hyundai group have depicted the most dynamic and intricate transformations, providing Hyundai, the mother company, its main subsidiaries (Kia and Hyundai Mobis), and its invested firms (Motional and 42dot), all of which have conducted research and separately tested autonomous driving systems. Apart from the above, key South Korean automakers include KG Mobility (KGM) and Renault Korea. Additional key parts suppliers embrace HL Mando. Additional key technology suppliers, mostly start-ups, comprise Rideflux, Bitsensing, ThorDrive, Vueron, Autonomous a2z, and Kakao Mobility. From 2016 to early 2024, MOLIT granted about 434 AV testing permits to these firms (see also IGARR, 2024). Most of them remain dynamic in advancing AI. For example, RideFlux in June 2024 secured MOLIT's permit to test its Level 5 autonomous driving (everywhere driverless, according to the US *Society of Automotive Engineers (SAE)* standard).

Another significant transformation is an open (R&D) innovation system extended on the above technology capability buildings. *Experts have emphasised that multi-layered domestic and international R&D partnerships and co-investments have accelerated the technology development of the Korean participating companies.*

According to company reports, Hyundai unveiled its initial self-driving car, the Ioniq, in Las Vegas in 2017, and successfully demonstrated a 118-mile highway test drive of its Nexo AVs in 2018. However, in 2020, it decided to partner with Aptiv, a US firm specialising in advanced self-driving technology, to establish a joint venture, Motional, to advance Level 4 (driverless but in a restricted domain) AV development and commercialisation in the US. Their company reports and websites reveal that, among these firms, large companies lead the country's AI- and automotive-based R&D investments, mostly financed in-house. Strongly interacting with *government agencies and research institutes,* they influence part of the design of government R&D-supported projects and partly co-finance and receive support from them. Smaller firms, particularly technology start-ups, depend more on financial support and research institutes through these projects. In 2020, MOLIT, the MSIT, and related government agencies established a seven-year (2021-2027) R&D framework project (under the National R&D Innovation Act) comprising 84 sub-projects across 30 missions to support the development of autonomous driving technology (see also Won, 2020).

*Some experts with automotive backgrounds underscore that universities have played a smaller role in R&D support for automotive firms; they have been more interested in other AI areas. Specific research institutes, such as KATRI, Korea Automotive Technology Institute (KATI), Korea Advanced Institute of Science and Technology (KAIST), KISTEP, and others, have played much greater roles in the transformations through government R&D projects. All the above dynamic R&D-based AI networks, between firms and/or firms and government agencies and research institutes, have significantly contributed to the system's technological development.*

From law reviews, the Act on Motor Vehicle Management, which governs the performance and standards of automobiles and automobile parts, was amended and enforced in 2020 to cover details governing Level 2 and Level 3 autonomous driving safety standards consistent with the SAE standards. The rules are also integrated into the deliberations of the working parties for the United Nations Economic Commission for Europe (UNECE) World Forum for Harmonisation of Vehicle Regulations (WP.29) and UN Regulation No. 79 (see Lee et al., 2020). MOLIT has attempted to comply with the updated SAE standards. The *institutions* are the frames that support the above technology creation and the product innovation below, although they have transformed more slowly than they have.

*Product innovation*

From company reports, under the above expansive layers of technology development, the automakers have led the commercialisation of AI technologies as multifaceted product innovations. They have transformed their factories to produce new, higher-quality electric vehicles (EVs) and parts that are better suited to autonomous driving systems than those in traditional combustion vehicles. In addition to ML for autonomous driving, they have utilised DL for concept development and the design of AVs and components. Besides the whole AVs (cars, vans, trucks or buses) and CAVs, they have developed new related technology solutions, software, platforms and parts for sale. *Parts suppliers and technology suppliers* have done the same, except for producing whole vehicles. *Interestingly, experts with automotive backgrounds indicate that, though competing, these transformers also position the others as their business-to-business (B2B) consumers for their new original equipment manufacturer (OEM) products. Their expected B2B consumers also include those in PBV, robotaxi, and autonomous logistics businesses—their new market models explicated below. Some experts argue that key transformations have been driven mainly by Korean companies, given that subsidiaries of foreign companies in South Korea, such as Renault Korea, have undergone AI-related transformations abroad.*

Company reports indicate that Hyundai has commercialised a series of conventional cars in new markets, including the Kona and Ioniq SUVs. Kia has commercialised the EV9 SUV, and KGM has commercialised the Korando e-Motion SUV. Competing with parts and technology suppliers, all three automakers have also developed new AV-related solutions, software, and platforms. Some competitors have intensively utilised AI networks to commercialise new OEM products. An AV platform provider, Hyundai Mobis, has also partnered with Velodyne Lidar to mass-produce AV lidar systems. KGM has collaborated with Pony.ai and Autonomous a2z to produce many of the new products.

According to their websites, other producers have relied on their own and newly acquired companies. Company reports indicate that Samsung and its subsidiary, Harman, supply AV platforms, semiconductors, software, sensors, control systems, vehicle audio and displays, and cameras. HL Mando and its subsidiary, HL Klemove, develop their own technologies to produce high-resolution cameras, 4D imaging radars, lidars (laser-based sensors), in-cabin sensors, and high-performance autonomous-driving control units for sale. Driven by AI, these automotive part producers have also commercialised some of the above innovations in the robotics market. Small technology startups, including Bitsensing, ThorDrive, and Vueron, have developed new technology solutions and parts for which they have a strong OEM sales presence. *However, many experts highlight the transformation of product innovations to cover vehicle-to-everything (V2X), in-vehicle infotainment (IVI), and CAV segments, where related software increasingly depends on Gen AI. They note that these new segments are the channels through which technology suppliers from the ICT sector have initially transformed into the automotive sector, with their strengths in networks, big data, cloud resources, the internet of things (IoT), and AI. Some newcomers have utilised newly established AI networks with existing automotive firms. Others have commercialised new products on their own. They have actively networked under the cooperative intelligent transport system (C-ITS), mainly supported by government agencies.*

According to company reports, SKT has partnered with Kia to develop new 5G-based V2X products and has collaborated with many automotive firms to improve their quality. In addition to sensors, cameras, and AV system platforms, KT has also produced cellular vehicle-to-everything (C-V2X) readers for sale. Collaborating with Magna, LG has integrated IVI and cross-domain data sharing with other software-defined vehicle (SDV) components for the new markets. *In depth, several experts comment that the levels of the above product innovations meet Level 4 self-driving* *standards, surpassing the limits of the above-established (2020) standards (institutions), which have evolved more slowly. This is because the above South Korean producers have targeted not only Korean but also global B2B and final consumers.*

For potential South Korean consumers, a 2023 Statista survey found that more than 61% regarded AVs as future-oriented despite concerns about current levels of driverless technology. About 40% of respondents to the 2024 survey were aware of some of their functions and were considering purchasing an AV. However, about 49% of them perceived that a Level 3 AV was the safest option (see Yoon, 2024). These potential consumers have then somewhat transformed themselves to see the opportunity to exploit product innovations, although their transformations have lagged behind the producers.

*Business model innovation*

More dynamic and strongly interacting with the above production-related activities have been the business model innovations—launching new multidimensional businesses connected to AV-based ride-hailing and logistics services and robot markets. They are founded on ML. This section examines only AI-driven business model innovations, not those that are non-technological or based on older automotive technologies. Based on information obtained from their websites, the above new markets are the interactive results and consumers of AI-based self-driving technology development and product innovations. Still, they extend beyond simply adding ICT to CAVs or expanding new product segments previously explicated. *Experts note that these new markets differ from selling AVs and CAVs as final products to final customers, given that the vehicles and their related technology solutions, software, and platforms are intermediate supplies for the production of these new markets for final customers. Some remark that the emerging autonomous ride-hailing, logistics, and robot markets in South Korea are part of the overall mobility market, which is also driven by electronics, ICT, and other sectors. Many experts indicate that, in these new business models, automakers and parts suppliers must face broader competition, especially from new technology suppliers and startups specialising in electronics, ICT, and related applications. The newly required supplies encompass not only AVs and their related components, but also technology solutions, software, and platforms required for the management of ICT, applications, and services in the new mobility systems.*

From websites, RideFlux, a *technology supplier startup*, is the first operator of an autonomous ride-hailing service in South Korea, with its Level 2 and later Level 3 roboshuttles operating in Jeju Island in 2020. Since 2021, the company has commercialised both ride-hailing minivans and robotaxi services; it later upgraded the services to Level 4 autonomous driving. From websites, more operators have entered and later transformed their initial pilot services, with lower levels of technology in designated zones (accumulating to an overall 34 zones in 2024 according to IGARR, 2024), into paid autonomous driving services with higher levels of technology in restricted markets. With support from *MOLIT and local government agencies*, especially in transportation, ICT infrastructure, and traffic data, robotaxis were commercialised in 2021 in Seoul, Gyeonggi Province, Jeju Island, *and Daegu*. The operators included *automakers*, such as Hyundai, and *technology-supplier startups, including 42dot, RideFlux, Sonnet, SWM, Kakao Mobility, and SoCar, the latter two of which also have expertise in ride-hailing online applications* and management (see also Lee, 2022). Gen AI progressively improves these applications, management platforms, and software. Finally, with the support of *Anyang City*, KT planned to operate a self-driving bus in the city in 2024.

Slower than the technological developments of the above operators, South Korea's laws and standards for commercialising Level 4 self-driving were not issued and enforced until 2024. *Experts with automotive backgrounds indicate that this is a reason leading automakers and technology suppliers, such as Motional/Hyundai and Samsung, have initially attempted to commercialise their Level 4 robotaxis in the US. Without such new institutions, amendments to existing laws have temporarily allowed MOLIT (and KOTSA) to assess and authorise AVs and grant permits for autonomous driving services at all levels of technology on a case-by-case basis.*

According to law reviews, the enactment of the Self-Driving Vehicle Act and the amendment to the Automobile Management Act that allow Level 4 self-driving vehicles were not enforced until March 2024. Although more Level-4-related standards covering safety, cybersecurity, insurance, and a sustainable environment are still to be finalised (IGARR, 2024), additional Level-4 self-driving operators have recently appeared in South Korea for paid services.

*As in the product innovation process, experts emphasise that operators must select appropriate strategic partnerships and co-investors as solid bases for competition in the dynamic market.*

From their web portals, Hyundai and its partner RideFlux have just commercialised their codeveloped Genesis GV80-based Level 4 robotaxis in small markets in Seoul and Gyeonggi Province in 2024. Most recently, KGM has partnered with SW Mobility (SWM) to operate Level 4 robotaxis based on its Korando e-Motion SUV in the Gangnam and Seocho areas of Seoul, starting in October 2024. They plan to commercialise more paid services strictly without drivers in more areas in 2025. Examples of companies that extend autonomous driving systems into logistics services include two technology start-ups: ThorDrive and 42dot. Their websites indicate that ThorDrive has united with E-Mart to operate autonomous delivery vans in a restricted market in Seoul. Besides ride-hailing, 42dot has collaborated with Hyundai Glovis, part of the Hyundai Group, to operate logistics services for car owners and transport and freight companies. Many companies have developed robots for the new mobility market as product innovations, new inputs for parking and logistics services, and process innovations, as explicated below.

*Experts note that in these new markets, B2B customers are still the main consumers, and they have emerged gradually.*

*Process innovation*

Also, based on AI development activities, many automakers, parts suppliers, and technology suppliers have utilised AI to introduce and significantly improve operations. *Experts note that large companies in the sector have been intensively pursuing AI-based process innovations, with applications beyond autonomous driving. This is because the firms have generally diversified their industrial operations across several industries and have applied AI to them. Several experts indicate that these AI applications, especially new AI-based robots, platforms, and ICTs—which share concepts of connectedness and mobility with autonomous driving—have helped reduce costs and increase efficiency in manufacturing design, operations, logistics, and customer access.*

According to company reports, Hyundai has utilised ML through robots, including autonomous mobile robots (AMRs), AI-based delivery robots, and more. These have supported many operations involving services, logistics, and safety maintenance. Kia has advanced robot technology, such as the DAL-e delivery robot, and other automated manufacturing processes by AI at its smart factory, especially for the production of its electric vehicle, EV6. Another *automaker*, KG Mobility, has introduced a hybrid assembly line utilising robots and humans to produce both combustion- and electric-powered vehicles. Remarkably, Hyundai Mobis has developed an AI system that operates on "sound" to perform quality inspections of its production lines and determine quality accuracy.

According to company reports and web portals, SKT has integrated ICT, network, and data technologies with an AI-based mobility platform to increase efficiency. The company has also applied its autonomous-driving robot technology to streamline warehouse operations and autonomously transport goods. KT has used its 5G self-driving carts to improve operational efficiency and its logistics services. It has continued to build new human and organisational capabilities and to develop technology, utilising AI networks established with universities and research institutes, and partnering with Microsoft to propel KT's AI and ICT (AICT) service, thereby improving the company's operational efficiency. Generative AI is also utilised in AICT. Further, it has provided the AICT service to customised *B2B consumers* with approaches to improve operational management. Likewise, LG has integrated AI and digital technologies into its smart factory concept, helping reduce production defects and costs and improve productivity. Utilising ML, DL and Gen AI, LG has committed to providing such smart factory service, from planning and design to construction and operation, to its customised customers globally (see also O'Halloran, 2024). Lastly, Samsung has employed AI technologies and solutions in its operations. The firm has employed *AI networks*, partnering with Synopsys, to create AI-powered features in computer processor designs. However, AI-based process innovations among technology supplier start-ups have been few.

*Experts reason that this arises because start-ups have emerged with new organisations, technologies, and operations; they have not yet experienced old operations being streamlined and/or replaced by newer ones.*

## *Anticipating future AI-driven SSIP transformations*

*The interviewed experts generally expect the transformation of the South Korean automotive SSIP to continue accelerating in the near future. Some experts point to sustained investment in technology capability-building by automakers, parts suppliers, and technology suppliers as evidence of deeper, more diversified AI technology development.*

This is well triangulated with the company report on KT's instance in the recent renewal of technology capability building and technology creation, embedded in open AI networks with partner firms, universities, and research institutes across various AI fields.

*Other experts emphasise the continued commitment of automakers, parts suppliers, and technology suppliers to advancing AV technologies and their commercialisation. Also, they indicate that research institutes, government and public agencies have robustly continued supporting the development and commercialisation of more advanced self-driving technologies.*

Evidence from company reports and websites includes expanding autonomous driving development and applications by technology suppliers: Autonomous a2z and Mars Auto have developed self-driving trucks; the former has also developed self-driving tractors. As for the *AI network*, leading global competitors Hyundai and Waymo have just announced a multi-year strategic partnership to integrate Hyundai's Ioniq 5 with Waymo's sixth-generation fully autonomous technology. This partnership is expected to provide a basis for advancing future robotaxi services in 2026. In July 2024, KAIST used the MSIT Fund for Advanced Technology Innovation to support joint research with the Massachusetts Institute of Technology (MIT) on advanced autonomous driving. Previously, in June 2024, *MOLIT* granted RideFlux a permit to test more advanced Level 5 autonomous driving. *Korean Transport Institute (KOTI)* expects a launch of Level 5 AV in 2027. *KOTI* has also confirmed a continuation of C-ITS installation to all South Korean road infrastructure by 2030 (KOTI, 2024). *Seoul* has strongly supported its plan to implement safe self-driving infrastructure throughout the city by 2028. These developments are among the reasons why many experts expect South Korea to make substantial progress toward its policy goal of transforming half of newly registered cars into fully autonomous vehicles by 2035. On the consumer side, a survey has revealed that South Korean *consumers* also expect the arrival of fully autonomous vehicles in the years to come (Yoon, 2024).

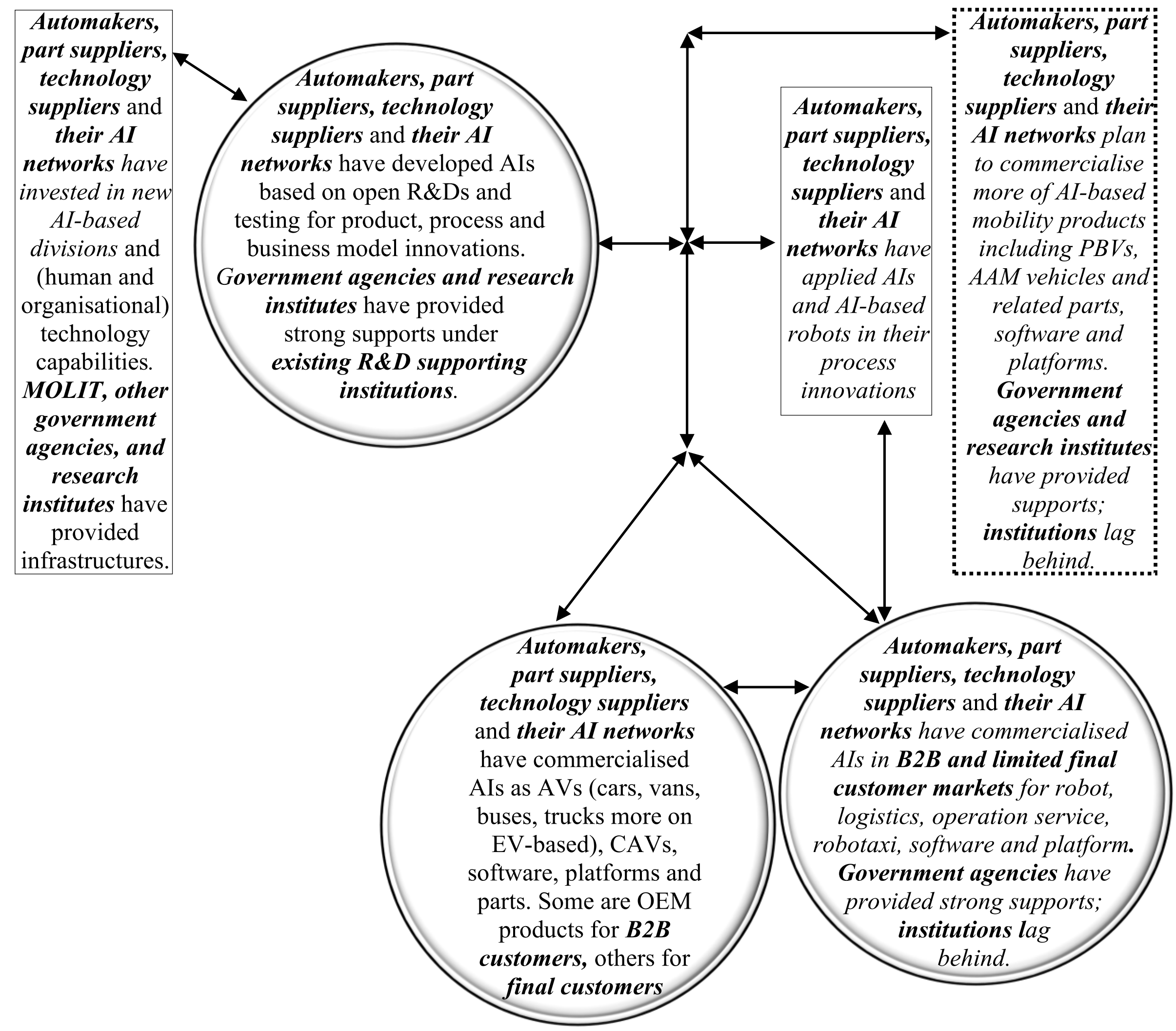
*However, many experts argue that the tipping point for future transformation, which supports their quantification of the SSIP components' transformations in 2027 (as illustrated in Table 2), is the continued business model innovations associated with PBV and AAM vehicles and their related software and platforms.* In 2024, Kia invested in the factory to produce the mid-sized PV5 PBV. The PBV can function as either a connected robotaxi, multi-seat shuttle, mobile office, store, or delivery and logistics vehicle equipped with IVI and tailored to the specific needs of *B2B and final consumers*. Utilising an *AI network*, Kia plans to partner with Kakao Mobility to operate a robotaxi after producing the PV5 in 2025. It has secured a contract to deliver PV5s to DHL for its delivery service. The Hyundai group has invested a large sum of money in and expects to support a variety of new parts for the PBVs. New human resources, technologies, materials, suppliers, and customers are expected to align with this new business model; more are expected as Kia produces large-sized PV7 in later years. *Also, an expert indicates Kia's new PBV factory as a trajectory of future AI-driven process innovations for the Hyundai group, as well as other producers.* According to company reports, the factory's production process is expected to utilise more advanced ML, DL, and other AI-based technologies for automation, autonomous installation and correction of parts and vehicles, vehicle and component design, and quality inspection.

In the emerging AAM vehicle market, many experts have been surprised by the rapid pace at which automakers and parts suppliers (companies in the Hyundai group) and parts and technology suppliers (LG Uplus, KT, SKT, PLANA, etc.) have entered the market. Company reports indicate the Hyundai group prematurely developed AAM technology capability in its urban air mobility (UAM) division in 2019. In 2021, it transformed the capability into a firm, Supernal, to develop and commercialise its AAM product innovations, projected for 2028. Utilising *AI networks*, Hyundai and KT have collaborated in AAM: Hyundai and Supernal have developed electric vertical take-off and landing aircraft (eVTOL) and vertiports; KT has secured control and communication networks for AAM operation. From websites, SKT has partnered with Joby Aviation since 2022, aiming to use its strength in AI-based ICTs to combine with Joby's expertise in eVTOL as a basis for future aerial ridesharing. PLANA, a *technology startup* founded in 2019, has partnered with Globalvia Blunest and Jeju Air for AAM and vertiport developments and signed a contract to deliver eVTOLs to Hi-Air from 2030. KT and LG, which have recently positioned themselves as AI companies to utilise AI for all their process innovations and B2B consumers, as mentioned above, have also targeted AAM innovations. With existing plans and commitments in technological and marketing activities worldwide, all the above transformers are projected to continue the transformations in the near future.

*Further, experts noted the roles of MOLIT, the Korea Office of Civil Aviation (KOCA), MSIT, local and other government agencies, and universities and research institutes in supporting research, testing, and advancing AAM technologies and their applications* *to UAM*. They have supported demonstration contests between Korean (K)-UAM consortia, in which Korean AAM leading firms, including Hyundai, LG Uplus, and SKT, team up with their ICT and physical infrastructure providers and operators to achieve planned AAM-based transportation. According to MOLIT's reports, this has also helped establish safety and operating standards, in addition to those MOLIT had already integrated through its work with the US Federal Aviation Administration (FAA) and the South Korea-based Global Association for Advanced Air Mobility (G3AM). *Some experts critique a slow transformation under the K-UAM contest.*

*Figure 2*
The AI-driven Transformation of South Korean Automotive Sectoral Innovation System

| ***Organisational innovation* and technology capability building** | **Technology creation** | **Product innovation** | ***Process innovation*** | ***Business model innovation*** |
|---|---|---|---|---|




*Source:* Author's work

According to websites, the contest was planned for 2020 but held in 2024. Like the 2020 APSCAV law, the new *bill* to promote UAM, enacted in October 2024, has allowed MOLIT to administer and support R&D and demonstration projects at its discretion. Specific laws on AAM and UAM transportation and related infrastructures, safety, cybersecurity, insurance, and sustainable environment remain to be issued. *Nevertheless, experts expect MOLIT and other government agencies to continue playing a leading role in advancing AAM commercialisation in restricted areas by 2025 and more broadly across countries in the 2030s, supported by the gradual development and formalisation of the relevant legal frameworks.* According to its website, Hyundai recently conducted a survey and anticipates substantial AAM and UAM *customers* in the 2030s.

Figure 2 highlights the main dynamics of the AI-driven transformation of the South Korean automotive SSIP. The analysis identifies automakers, parts suppliers, and technology suppliers, along with their AI networks, as the leading transformers across production-based activities, driving a diverse set of complementary innovations. They have undertaken organisational innovations, investing in new AI-based divisions and performing AI-related (human and organisational) technology capability building. Such transformations have been well aligned with those of MOLIT, other government agencies, and research institutes, which have also provided matching infrastructure for the former groups of actors. As the two-way arrow signifies, this is a ground for leading transformers to undertake AI development. The technology creations (under the second column) encompass those under open R&D and testing for commercialisation as present and future product, process, and business model innovations. In this transformation process, government agencies and research institutes, and, to a lesser degree, universities, have also transformed themselves to support existing R&D institutions.

The importance of technology creation activities in the second column is evident, as they serve as a central driver of transformations in other activities and associated innovations, as depicted by the two-way arrows linking the three columns on the right to technology creation activities. Two other transformation centres are under the product innovation and business model innovation columns at the bottom of the figure. In the former, the four leading groups of transformers have commercialised AI technologies as AVs, CAVs, software, platforms, and parts, mainly for B2B consumers and some final consumers. However, as a two-way arrow connects the two centres, the former's B2B consumers are also in the latter centre, where they have commercialised AI technologies in new markets for robotics, logistics, operations services, robotaxis, and related software and platforms. Note that the government agencies have provided strong support in the latter case, whereas related institutions lag. Additionally, the two-way arrow linking the latter centre to process innovation activities indicates that the four leading transformers have applied robots from the new business model markets, as well as other AI technologies, to generate process innovations. Finally, the top-right section of the figure shows that the leading transformers plan to commercialise AI technologies through PBVs, AAM vehicles, and related ride-hailing services, software, and platforms. Note also that the government agencies have provided strong support in this case, whereas related institutions lag. All of the above would not be expected in the traditional automotive sector without AI.

## Discussion

The quantitative results presented in Table 2, which directly address RQ1, indicate a general trend: all automotive system components have undergone AI-driven innovation, and these transformations are expected to accelerate further. Slower transformers, embracing government agencies, research institutes, institutions, and consumers, imply strategic adjustments among their organisational leaders, related management, and individuals to achieve quicker transformations and gain potential benefits from AI. Related policy planners and implementers may also select appropriate policy instruments to shape their own transformations toward a more comprehensive AI-driven transformation of the automotive sector. Additionally, the detailed qualitative results, which directly address RQ2, enable the extension of strategic, policy, and theoretical implications as follows.

### *Strategic Implications*

As different forms of AI, mainly ML, DL, and Gen AI, have diffused into and been developed within the automotive business system, they have created opportunities for automakers, parts suppliers, and technology suppliers to lead the development of new technologies, production activities, and innovations. The augmented SSIP framework highlights how automakers and parts suppliers have expanded into new sectors by developing new and potential business models. These include robots, logistics, operational services, robotaxis, PBVs, AAM vehicles and their related parts, software and platforms. Conversely, the transformation of parts and technology suppliers from other sectors into the automotive domain is evident, as they seek to capture value from AI-driven product and business model innovations. One strategic implication of our study is that it indicates not only open R&D and the commercialisation of AI as manifold innovations in the automotive sector, but also an open automotive sector in which AI is emerging as a driver within the growing mobility sector.

Another strategic implication for automakers, parts suppliers, and technology suppliers worldwide is to independently or cooperatively invest in AI-related technology capabilities and R&D to develop and commercialise one or more of the above-explicated, attainable innovations, thereby surviving and seizing the opportunities arising from such transformations. This is supported by the above findings that AI networks have been intensively utilised and transformed by the three groups of firms, with co-investors and partners among themselves. They also encompass collaborations with government and public agencies, universities, and research institutes. All of them cover technology capability building, technology creation, and product, process, and business model innovations.

More strategic implications are drawn from the above case of consumers' transformations. With final consumers' transformations slower than producers' technological development and innovation, more consumer education and testing of these innovations are necessary. For the South Korean example, these presently involve the transformation from Level 3 AVs (in a survey (Yoon, 2024) now being well satisfying to average consumers) to Level 4 AVs.

Additionally, the proliferation of B2B consumers, along with product, process, and business model innovations in the expanding automotive-mobility sector, signifies ample opportunities for automakers, parts suppliers, and technology suppliers to continue AI-based transformations and reap the benefits. Lastly, tracing the impacts of AI on current and emerging business models reveals increasingly open sectoral boundaries in the presence of a widely applicable technology such as AI.

### *Policy implications*

The significant role of government and public agencies is emphasised as substitutes for, rather than merely supplements to, formal institutions when regulatory frameworks evolve too slowly to support the transformations of private actors and their AI-based innovations.

In South Korea, the government has employed actors such as MOLIT and relevant government agencies as policy instruments to articulate and enforce (imported and newly created) standards rather than laws, to accommodate private actors' swift commercialisation of AVs and robotaxis, and to anticipate the expected commercialisation of AAM in the years to come. Laws have later come to endorse their transformations.

This has practically expanded the roles of the South Korean government and public agencies to cover AI-based transformations, from technology capability building to technology creation, as well as present and future business model innovations. For South Korean automotive SSIP, government and public agencies have not been less important than universities and research institutes, which are already supported by existing research acts (Won, 2020; Yoon, 2024); they have here supported technology capability building, technology creation and (some) product, process and business model innovations.

### *Theoretical implications*

The traditional SSIP is tied to a group of products and focuses on knowledge (technology) creation for mainly product innovations (Malerba, 2002, 2004, 2005). The framework would have difficulty explaining the current phenomenon of automakers and parts suppliers expanding their product lines, production activities, and innovations into other sectors and domains.

The framework is then augmented, retaining its foundation in actors, their networks, and institutions, while allowing for a broader range of technologies, production activities, products, and innovations, thereby extending earlier evolutionary perspectives (Nelson, 1997; Metcalfe, 1998) to better capture the dynamic interactions among these components. It is the first time that organisational, process, and business model innovations (some of which have been developed for a long time) have been integrated into the SSIP framework. However, the analysis focuses exclusively on technology-based business model innovation, excluding non-technological forms.

Applying the augmented framework to the present study, the transformations of leading actors and their related networks and institutions can be traced not only in scale and across business functions that help to map out the holistic interactive automotive system and results, but also across open boundaries of related sectors, which provide broader, realistic, and valuable insights and strategic and policy implications. The augmented framework is expected to be useful for future studies examining the impacts of AI across different sectors, as well as the effects of other emerging technologies on the automotive and related sectors.

## Conclusion

This study aims to contribute a systematic investigation into AI's effects on the innovation-production transformation of the whole automotive sector.

The study addresses the gap in systematic studies on AI's impact on the automotive business system. It is based on the newly augmented SSIP framework, which serves as an input to the Delphi, expert interviews, and document analysis methods utilised. The key augmented parts added to the framework include organisational, process, and business model innovations, along with related production-based activities. Findings point to accelerating present and future transformations of SSIP components, among which automakers, parts suppliers, technology suppliers and their AI networks are leaders. Government and public agencies have changed slowly, while research institutes, universities, institutions, and consumers have lagged.

The expert assessments, interviews, and document analysis jointly indicate that intensifying interactions among SSIP constituents, AI technologies, and AI-based production activities and innovations have accelerated these transformations and are expected to continue doing so. Finally, some strategic, policy and theoretical implications can be drawn from the transformations as explicated above.

The findings on open sectoral boundaries in the presence of a new, widely applicable technology, such as AI, are in line with a previous study on the incorporation of the IoT, the internet of services, and cyber-physical systems in sectors with very rapid innovation. There, sectoral boundaries are not fixed and may change due to rapid technological innovation (Weber & Schaper-Rinkel, 2017). However, while this study highlights government and public agencies as partial substitutes for laws (institutions) in South Korea, Channon et al. (2019) and Maddaleni (2024) indicate that laws are necessary for the commercialisation of AVs and robotaxis in the UK, some US states, and some European countries.

Finally, a better understanding of AI's systemic impacts on the transformations of multiple, varied, and interactive business (production-related) functions and their matched innovations, as well as on the whole production-based innovation system that embeds them, is provided at each point in time. However, that requires space and limits comparisons with cases of interest, such as those in the US, Germany, and China. The bias on a particular area (here, South Korea) remains. However, as a theoretical implication for international and comparative research, the augmented SSIP framework can be applied to examine the impacts of AI on automotive sectors across different countries.

Many of the strategic implications in the Discussion section could be applied to international cases. These include the forms of international partnership and joint investment mentioned for AI-driven technology creation and commercialisation. They also embrace the growing, complex international B2B markets for AI-based automotive parts and services. Other significant implications for international producers and consumers are that wherever they introduce AI into the automotive sector, new related sectors emerge, offering new and potential business models: robots, logistics, operational services, robotaxis, PBVs, AAM vehicles and their related parts, software, and platforms. These are the AI-driven opportunities international players may select to realise. Finally, additional limitations include limited coverage of consumer adoption trends, evolving regulatory frameworks, and comparative analyses of regulatory challenges and international policies. Further research is needed to examine these aspects in greater detail.

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