Gaining Competitive Advantage with a Performance-Oriented Assessment using Patent Mapping and Topic Trend Analysis: A Case for Comparing South Korea, United States and Europe's EV Wireless Charging Patents

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Abstract of the Dissertation

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The government's efforts led to an increase in the total number of technology transfer cases and technology transfer rate, but not in licensing revenues in Korea. The number of technology transfer cases and technology transfer rate are process-oriented variables. While important, they provide limited information on how the transferred technologies are utilized. Therefore, the dissertation focuses on explaining the qualitative performance of patents. This dissertation develops a comprehensive analytic toolkit to assess patents systematically and holistically by modeling their value, rarity, inimitability, and non-substitutability (VRIN) attributes. As a case study, the VRIN of electric vehicle (EV) wireless charging patents is modeled to address the qualitative performance of their potential for competitive advantage in technology transfer and commercialization.

The dissertation integrates two research techniques, topic trend analysis using topic modeling and patent mapping, to compare the competitive advantage, in terms of VRIN attributes, of EV wireless charging patents registered in the Korean Intellectual Property Office

(KIPO) and compares them to similar patents in the United States Patent and Trademark Office (USPTO) and European Patent Office (EPO).

The outcomes of the toolkit for this pilot of EV wireless charging technology are as follows. First, the topic trend analysis shows that connector is a topic that increased in proportion between 2008-and 2020, which tells that wireless charging may not yet be commercially available. Second, the patent map shows that KIPO patents have lower VRIN attributes than USPTO patents; and have lower value and inimitability attributes but higher rarity and non-substitutability attributes than EPO patents. In addition, Korean public organization patents have higher value and inimitability attributes but lower rarity and non-substitutability attributes than Korean private organizations.

The dissertation provides evidence that if Korea increases financial investments to improve the VRIN attributes of EV wireless charging patents in KIPO to the level of USPTO patents, then it can provide a way to improve the technology transfer performance in the EV case. However, the primary focus for South Korea is to increase the number of VRIN patents in the field of EV wireless charging patents. More importantly, the toolkit can be used to assess other patented technology.

Keywords: Competitive Advantage, Resource-Based View, Performance-Oriented Assessment, Patent Mapping, Topic Trend Analysis, EV Wireless Charging, Korea Patents

Dedication Page

This dissertation is wholeheartedly dedicated to my beloved parents, sister, brother-in-law, and niece, who have been my biggest supporters during my education.

And most importantly, to God Almighty for the guidance, strength, and protection.

"I will give thanks to you, Lord, with all my heart;
I will tell of all your wonderful deeds."

Psalms 63:3-4

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List of Abbreviations

AUTM	Association of University Technology Managers
BEV	Battery Electric Vehicles
CEC	China Electricity Council
CEM	Clean Energy Ministerial
CEV	Fuel Cell Electric Vehicles
EPO	European Patent Office
ETRI	Electronics and Telecommunications Research Institute
EUIPO	European Union Intellectual Property
EV	Electric Vehicles
EVCI	Electric Vehicle Charging Infrastructure
EVI	Electric Vehicles Initiative
EVSE	Electric Vehicle Supply Equipment
HEV	Hybrid Electric Vehicles
IEA	International Energy Agency
IEC	International Electrotechnical Commission
INDOT	Indiana Department of Transportation
IP	Intellectual Property
KAIST	Korea Advanced Institute of Science and Technology
KEPCO	Korea Electric Power Corporation
KERI	Korea Electrotechnology Research Institute
KIIP	Korea Institute of Intellectual Property
KIPO	Korean Intellectual Property Office
KOTI	Korea Transport Institute
KTTC	Korea Technology Transfer Center
KW	Kilowatts
LOF	Local Outlier Factor
MI	Magnetic Inductive
mm	Millimeters
MOTIE	Ministry of Trade, Industry, and Energy
MR	Magnetic Resonance
MSIT	Ministry of Science and ICT

mW	Milliwatts
OECD	Organisation for Economic Co-operation and Development
PCA	Principal Component Analysis
PHEV	Plug-in Hybrid Electric Vehicles
R&D	Research and Development
R&BD	Research and Business Development
RBV	Resource-Based View
TF-IDF	Term Frequency Inverse Document Frequency
TRL	Technology Readiness Level
TTCP	Technology Transfer and Commercialization Plan
TTOs	Technology Transfer Offices
UIC	University-Industry Collaboration
USPTO	The United States Patent and Trademark Office
V2G	Vehicle-to-Grid
VRIN	Valuable-Rare-Inimitable-Non-substitutable
OECD	Organisation for Economic Co-operation and Development

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This dissertation would not have been possible without the support of many people.

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Lastly, big thanks to the #RSTAT Community for sharing their knowledge and information.

Chapter 1 Introduction and Overview

The worldwide industrial development pattern has changed because as intangible knowledge and innovation influence the national competitiveness, countries around the world are expanding their investment in research and development (R&D) (Congressional Research Service, 2020; Lee & Jo, 2018) and are making policy efforts to utilize the generated knowledge efficiently (Knoll, 2003; Wu et al., 2007). Hameed et al. (2018) noted that Korea is at an important point in its economy and is in the middle of its transformation from a "catch-up" phase that relies on technology adaptation to generating its creativity and knowledge. In addition, many experts are interested in seeing how Korea responds to this transformation because Japan, which has similar economic growth as Korea, has gone through an era of having an "economic miracle"[1] followed by a "lost decade"[2] era (Hameed et al., 2018; Zoli, 2017).

To cope with the transformation and control the mass-producing valueless patents, the Korean government shifted its R&D focus to the era of Research and Business Development (R&BD). In addition, the Korean government focused on developing the country's technical capacity through increased R&D investment (Kim, 2001; Yang, 2011). The Korean government reformed its R&D ecosystem to focus on investment that leads to profit and business achievements. It included investments in actual technology transfer and commercialization licensing deals instead of performance indicators such as patents, publications, and newly hired

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[1] The “economic miracle” is a term that describes a “period of rapid economic growth that exceeds expectations” (Business Dictionary, 2016a)

[2] The “lost decade” is a term that describes the Japanese economy between the early 1990s and 2000s, in which the economic expansion came to a halt, and the real estate and the stock market crashed causing immediate debt crisis (Business Dictionary, 2016b)

R&D Personnel). Policies and support programs are now focusing on changing from resource expansion to performance orientation (Yang, 2011).

Through the benchmarking of foreign policies and technology commercialization organizations, Korea has laid the foundation of technology transfer and commercialization activity by the enactment of various policies, such as its *Technology Transfer and Commercialization Promotion Act, Technology Transfer and Commercialization Plan (TTCP)*, and *Special Act of Promoting Venture Companies*[3] (Han, 2018; Lee, 2013). For example, *Discovery of a Demanding Company to Support Technology Transfers* is an annual support program managed by the Korea Institute for Advancement of Technology (KIAT) to promote technology transfer-commercialization. The support program assists the technology transfer offices (TTOs) and the technology receiving firms by 1) assisting TTOs in finding a pool of public institutions who wish to transfer their technology and 2) assisting the receiving firms through funding the transfer and supporting the development of products. The number of firms participating in the support program has increased from the previous year. However, there has not been an increase in the firms' sales, revenue, or other direct performances (Park and Chang, 2020). Other financial support programs, such as the *2021 Excellent Technology Commercialization Support Project* and *Scale-up technology commercialization program*, support firms and their technology transfer/commercialization processes in 2021 (Ministry of SMEs and Startup (MSS), 2021).

Moreover, the government has encouraged universities and government research institutes (GRI) to establish their own TTOs (Han, 2018). Therefore, universities have established university-industry cooperation (UIC) division and included a TTO department.

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[3] An act that was enacted for the enhancement of the competitiveness thereof, by promoting the conversion of existing enterprises into venture businesses and the establishment of venture businesses (National Law Information Center, 2018)

Intellectual property (IP) rights management and technology transfer activities were actively carried out through the TTO. And as a result, the number of patents and the number of technology transfer cases at universities have significantly increased since 2003 (Han, 2010). Korean universities' number of patents registered in the Korean Intellectual Patent Office (KIPO) increased by 6.6% annually from 2015 to 2019 (Jung, 2021). Also, the number of patents registered in overseas IP offices by Korean universities increased by 16.6% annually in the same period. Interestingly, among the total patents registered in 2019, the top ten universities in Korea owned 38.6% of domestic patents and 64.6% of overseas patents (Jung, 2021). Table 1 shows the Korean university-owned patents registered in domestic and international IP offices

Table 1 University-owned patents registered in domestic and international IP offices

Patents	**2015**	**2016**	**2017**	**2018**	**2019**
Domestic	62,259	66,946	72,434	77,567	85,775
International	5,606	8,324	9,565	10,335	12,099

Source: Jung (2021)

Ok and Kim (2009) examined the relationship between the R&D budget and the output of universities. The authors found a positive relationship between the R&D budget and the number of technology transfer cases, royalties, the number of new technologies developed, and the number of publications in the university. Despite these efforts, Korea's technology transfer performance still lagged behind advanced countries like the United States (Ok & Kim, 2009; Park & Park, 2017). The World Bank (2020) presented the *R&D Transfer Index*, which calculated the likelihood of national R&D being commercialized. In 2019, South Korea received a 2.63 compared to the United States (2.74), Japan (2.77), and China (3.28). In contrast, Switzerland had the highest value with 3.58, while Uruguay, Hungary, and many small countries received a 0. The world median was about 2.6, while the median for East Asia and the Pacific region was about 2.77.

Choi (2021) examined the government support programs for technology transfer and commercialization in Korea and found that most programs were focused on establishing the technology market and strengthening the technology transfer and transaction competencies. The author stated that for commercialization to succeed, laboratory- technology must be further developed into a mature technology that can be applied to products. However, this stage requires time, effort and funds, and the government, corporations, universities and research institutes are hesitant in investing more resources. Furthermore, the government support for technology transfer and commercialization is low (within 1-2 billion won) compared to the effort and time to commercialize (Choi, 2011).

1.1 Problem Statement

1.1.1 Problem 1: Lack of Performance-Oriented Variables in Technology Transfer

Park (2008) stated that due to the increased investment in R&D of government-funded research institutions and universities, the total number of technology transfer cases, the total number of patents, and technical fees have increased in Korea. However, the *qualitative efficiency of technology transfer*[4] has not changed. Moreover, Lee and Kim (2013) highlighted that Korean universities and government-funded research institutions lack the commercialization capabilities (i.e., lack of funds for the universities and lack of R&D productivity for the government support institutes) to create markets and job creation abilities.

Similar results have been shown in the firms that have received technologies through the support programs. Furthermore, Park and Park (2017) stated that Korea, which lacks existing

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[4] Lee (2013) defined qualitative efficiency in two ways: a) the total technology transfer royalties, or b) the ratio of the transfer royalty to the total investment per technology transfer contract.

resources, needs to emphasize R&D as a strategic means to strengthen national competitiveness and foster new growth industries. While Korea has continuously expanded its investment in R&D and ranked in the top two among OECD countries for R&D expenditure (Organisation for Economic Co-operation and Development, 2020), the increase in R&D investment did not lead to a substantial increase in market value (Park & Park, 2017). The authors also emphasized that Korean government research institutes/universities' R&D performance and the number of technology transfers did not show a huge difference compared to the United States, where the total public R&D investment is 6.9 times more than South Korea. The number of technology transfer contracts (as of 2012) was 6,676 cases in South Korea, with 27.1% of the technology transfer rate, compared to 7,897 cases in the United States, with 33.9% of the technology transfer rate. The technology transfer rate is defined as the ratio of the number of technology transfer cases and the number of newly developed technology (Park & Park, 2017). The difference in technology transfer rate between the two countries is not huge. This may be because South Korea has a reputation for leading in high technology areas and was ranked fifth in Global Innovation Index, which ranks countries by their capacity and success in innovation (Global Innovation Index, 2021), and perhaps has the potential to surpass the United States in terms of technology transfer rate.

The number of technology transfer cases and technology transfer rate are process-oriented variables. While important, they provide limited information on how the transferred technologies are being utilized as it does not emphasize the qualitative performance of the technology. Therefore, a different perspective of technology transfer and commercialization should be considered to assess the activity qualitatively. Therefore, the dissertation focuses on explaining the qualitative performance of patents so that the technology can give researchers and technology investors a more competitive advantage[5].

Various technologies are available for technology transfer, but with the Korean government's growing interest in clean energy vehicles, this dissertation research focuses on wireless charging patenting in the Electric Vehicle (EV) industry as a case study. As a result, it led to an increased number of patents in the EV industry (KIPO, 2017). Furthermore, the Ministry of Science and ICT (MSIT) (2015) once announced the technology transfer activity of electric vehicle technology from one of the public research institutes to a private firm. Therefore, the dissertation focuses on patenting in the EV industry as a case study.

1.1.2 Problem 2: Lack of EV Adoption in South Korea Despite Increased Support

South Korea has taken the initiative to invest in the electric vehicle industry, along with four other industries (semiconductor/display; bio; IoT home appliance; and energy) (Kim & Kim, 2019). Korea plans to increase the number of clean energy vehicles, such as electric vehicles and hydrogen vehicles and has extended subsidies for clean energy vehicles (Kim & Kim, 2020). Despite the effort, the lack of EV adoption has been the main problem in South Korea. South Koreans are reluctant to purchase EVs, as only 0.05% of the automobile market was EVs in 2013 and slightly grew to 2.3% in 2018 (Yoon, 2022). As the South Korean government aims to increase the market share of EVs in the sales of new vehicles to 33% by 2030 (Yoon, 2022), the government must emphasize the importance of the qualitative performance of EV patents.

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[5] A firm is said to have competitive advantage when it implements a value creating strategy that are not implemented by current and potential competitors (Barney, 1991).

1.2 Proposed Solution

Therefore, as a pilot study of the competitive advantage of patents, this dissertation assesses the EV wireless charging patents' sustained competitive advantage by mapping their value, rarity, and inimitability. Again, the dissertation focuses on patenting in the EV industry as a case study. The dissertation is a patent analysis on electric vehicle wireless charging technology patents in the United States Patent and Trademark Office (USPTO) database, similar patents in the European Patent Office (EPO) and potentially transferable patents listed in KIPO. Lessons and applications learned from looking at patents worldwide can be helpful to Korean cases.

This dissertation uses patent mapping and topic trend analysis to develop a comprehensive analytic toolkit to help business managers and R&D staff assess patents systematically and holistically by modeling their value, rarity, inimitability, and non-substitutability (VRIN). In particular, as a case study, the VRIN of electric vehicle (EV) wireless charging patents is modeled to address the qualitative performance of their potential for competitive advantage in technology transfer and commercialization.

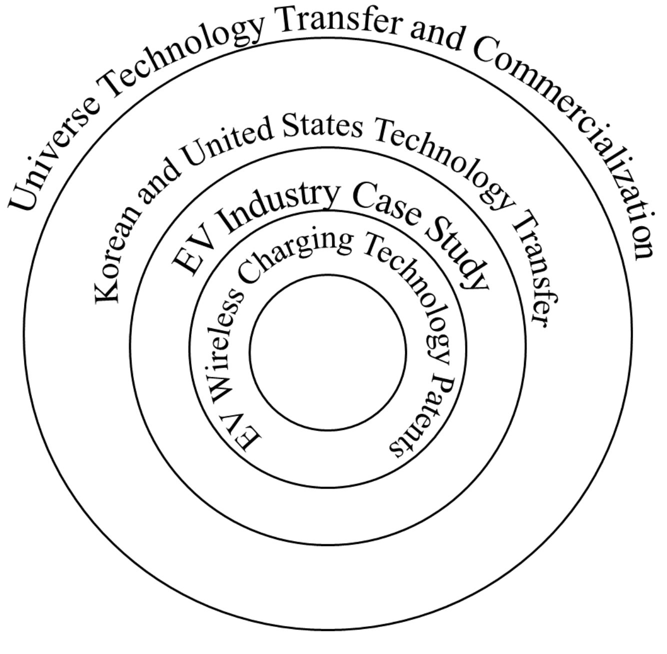
According to Porter (1990), a nation’s competitiveness depends on the capacity of its industry to innovate and upgrade. Therefore, the dissertations use patents, and their competitive advantage in terms of VRIN attributes to examine the international competition between South Korea, the United States and Europe in the EV industry.

The research outcome of the dissertation provides R&D teams with a way to identify patents with sustained competitive advantage attributes, thus creating a higher likelihood of commercialization success. Furthermore, this toolkit will likely alleviate technology resistance because it provides objective means to identify patented technologies with VRIN and competitive advantage. Once end-users have knowledge of the wireless charging technologies as shared by experts, then end-users would likely be less resistant to adapt.

1.3 Boundary of the Study

Figure 1 shows the concentric circle to delineate the boundaries of the dissertation. The literature review touches on the five areas: the universe of technology transfer and commercialization, the Korean and United States technology transfer and commercialization, the electric vehicle industry case study, and the EV wireless charging patents. The dissertation plans to examine the Korean and the United States' technology transfer and commercialization ecosystem under the universe technology transfer and commercialization level. Furthermore, using an electric vehicle wireless charging technology as a case study, the dissertation plans to analyze and compare patents filed by the Korean public institutions to patents filed by US assignees and Korean private organizations to provide helpful lessons and applications.

Figure 1
Concentric Circle Model of the Dissertation



Chapter 2 Literature Review

2.1 Introduction

In this chapter, the dissertation looks at the prior research on technology transfer & commercialization and electric vehicles and based on this, the dissertation identifies gaps that warrant further research. As a start to the literature review, the dissertation defines technology transfer and commercialization in Section 2.2. In Section 2.3, the dissertation overviews the technology transfer and commercialization process. Section 2.4 provides details on the technology transfer and commercialization status in South Korea. Section 2.5 reviews the electric vehicle (EV) industry and charging technologies. Section 2.6 compares the different patent offices and their characteristics and examines the EV patent registration status. Finally, Section 2.7 presents the identified research gaps from the literature review.

2.2 Technology Transfer and Commercialization

Today, open innovation, co-creation, and many other collaboration activities are common in nurturing innovative ideas and knowledge for the world. Another important activity is the transfer of technology and knowledge for technology commercialization. Technology commercialization through technology transfer is vital in today's economy and receives substantial attention from many countries. According to Kirchberger and Pohl (2016), technology transfer and technology commercialization originally had different meanings, but the two terms are used interchangeably in today's literature. The economists first used the term technology transfer, and its original definition was the development and diffusion of innovation within the society rather than commercialization (Zhao and Reisman, 1992; Galbraith et al., 2006). Some literature does tend to differentiate the terms. However, those studies are by economists dealing with only economic impacts (Kirchberger & Pohl, 2016).

Mayer and Blaas (2002) highlighted that firms, especially SMEs, began to utilize technology transfer as a strategy to keep themselves competitive in the globalization era. Due to the small R&D department and the firm size, many SMEs have a hard time developing innovation but still need to be competitive. Furthermore, in recent studies, the definition has been narrowed down to firm levels, as Morberg and Moon (2000) defined technology transfer as the *"movement of scientific knowledge from one party to another."* Similarly, Roessner (2000) defined it as the *"movement of know-how, skills, technical knowledge, or technology from one organizational setting to another."* In the United States, technology transfer at universities is managed by TTOs at many universities. The TTO can license the technology to a large corporation or license to a university's spinoff company. This licensing is a transfer of technology (Association of University Technology Managers (AUTM), 1998).

Morberg and Moon (2000) defined technology commercialization as "when the transfer involves the making or selling a product to provide a financial return to the inventor." Similarly, Ghazinoori (2005) defined it as "creating a suitable product with a fair price in an attempt to satisfy market demand." Carayannis et al. (2015) defined it as "any form of commercial usage of IP, including the cession of the rights, licensing, and internal use of IP by universities and commercialization by specialized companies" and is connected to "…scientific and technical entrepreneurship, business incubation, the creation of new companies, the implementation of innovative projects, and, of course, licensing". Finally, Kirchberger and Pohl (2016) defined it as "the process of transferring a technology-based innovation from the technology developer to an organization utilizing and applying the technology for marketable products."

The overall notion of technology transfer can be understood as a movement of technology from one environment to another, where it comes to fruition. On the other hand, technology commercialization is an innovative activity to create new products or processes by utilizing technologies and knowledge that may or may not be acquired from technology transfer to improve the overall procedure. Therefore, for the dissertation that deals with Korean technology transfer and commercialization activities, the following definitions of technology, technology transfer, and technology commercialization are defined by the Technology Transfer and Commercialization Promotion Act (National Law Information Center, 2018; Park & Park, 2017) is used.

- Technology: a) Intellectual Property (Patents, Utility Models, Designs, Semiconductor Integrated Circuit Design, and Software); b) Capital Goods with Intellectual Properties; c) Any information regarding a) or b) and d) Scientific, technological and industrial know-how that can be transferred or commercialized.
- Technology Transfer: When the owner of the technology (including those who have the authority to dispose of the technology) either a) transfers, b) grants a license, c) provides technical guidance, d) conducts joint research, e) creates a joint venture or f) goes through an M&A of the technology to another individual, institution, or firm.
- Technology Commercialization: Developing, producing, selling a product using technology or improving the technology in the process.

2.3 Overview of the Technology Transfer and Commercialization Process

2.3.1 Legal Methods of Technology Transfer

Table 2 shows other legal methods of technology transfer. Choosing the right legal methods to transfer the technology between actors depends on many factors such as the maturity of the technology; the type of firm that is planning to receive the technology; potential future partnerships in the future; and other potential benefits other than the technology itself (Carayannis & Alexander, 1999). Further, Carayannis et al. (2015) stated that the most common partnership pursued by academic institutions to take their researchers' inventions to the commercial stage is through a licensing agreement. A license agreement as a licensing revenue and franchise royalty payments of technology mostly occur in intra-company transfers between parent firms and their subsidiaries (Carayannis et al., 2015).

Carayannis et al. (2015) proposed two "relatively simple" technology commercialization methods: 1) license agreement with a firm that is interested in using the technology, and 2) creating a spinoff with the university IP. Furthermore, Han (2017) stated that the first step to commercialization is to patent the technology via university-industry collaboration (UIC). At this point, what is to be commercialized from the firm's perspective becomes what is to be transferred from the university's perspective.

Table 2
Technology Transfer Methods and Definitions

Source	Technology Transfer Method	Definition
Carayannis & Alexander, 1999	Cooperative Research and Development Agreements (CRADAs)	Comprehensive legal agreements for the sharing of research personnel, equipment, and intellectual property rights in joint government-industry research
	Spinoffs	Formed to commercialize a technology originated in a parent organization such as a university, a Federal R&D laboratory, or a private company.
Shamsavari et al., 2002	Licensing Agreement	The licensor allows another company to use or sell these rights in return for a financial reward (royalties)
	Machinery Supply Contracts	Supply of capital goods such as machinery and spare parts
	Franchising	Similar to licensing, but involves an ongoing relationship between the supplier and the receiver
	Management Contracts	Management, marketing, and technical service contracts that involve the transfer of skills and technology in return for a fee
	International Subcontracting (Outsourcing)	A manufacturing firm in a developed country subcontracts the manufacturing of its goods, parts, and components to a firm in a developing country to take advantage of lower labor costs and higher incentives by the host government
	Joint Ventures	Creation of a new company through partnering with two or more other companies
Chiesa et al., 2008	Transfer of Ownership	A business transaction, such as assignment for a money consideration, contribution to a company (technology sale paid with shares), or joint venture (with selling agreement).
	Patent License Agreement	Licensing the right to perform based on the patented technology without providing any instructions to use it
	Patent & Know-how License	Licensing of the technology, in which part of it is protected by a patent and some parts are not, according to the agreement
	Copyright License	The receiver can use the software for a limited or unlimited time, according to the agreement, and has to pay a charge.

	Joint Venture with License Agreement	The owner controls and manages directly, with a partner, the intangible asset to obtain profits in the future
Goodman & Dingli, 2017	Licensing	The exchange of access to a technology (and perhaps associated skills) from one company to another for a regular stream of cash flow
	Cross-licensing	An agreement between two firms to allow each other to have access to specific technologies owned by the firms
	Strategic supplier agreement	A long-term supply contract, including guarantees of future purchase and greater integration of activity than a casual market relationship
	Contract R&D	An agreement under which one company or organization conducts research in a specific area on behalf of a sponsoring firm
	Joint and cooperative R&D agreement	An agreement under which two or more companies agree to cooperate in a specific area of R&D or a specific project
	R&D cooperation or research joint venture	The establishment of a separate organization, jointly owned by two or more companies, which researches on behalf of its owners
	Research consortium	Any organization with multiple members formed to conduct joint research in a broad area
Lim & Lee, 2015	Licensing	Contract in which a licensor receives a technology fee from a technology licensee and grants a license for a certain period.
	Assignment	Sale of technology rights to technology consumers
	Cooperative Research	Also known as joint research, the principle of sharing costs or distributing costs, and ownership of intellectual property rights
	Spinoffs	A company that has a separate business unit from the main organization due to expanded business areas
	Joint Venture	Similar to joint research, but cooperates in all business areas, not just the R&D sector
	Merger & Acquisition	Instead of individually accessing the technology through licensing, acquiring the technology and related facilities through taking over the supplier

2.3.2 Technology Commercialization Process

Gardner et al. (2004) examined the technology transfer process steps from the idea stage to the commercialization stage. The technology transfer and commercialization start with an ideation stage. Universities and government research organizations dedicated staff to 1) develop new technology and 2) examine the commercial potential of the technologies invented. The next steps are to examine the invention and file for appropriate intellectual property protection. It is essential to define the technology's functionality and conduct a technology assessment to see any market potential in these steps. The following steps are to assess the market (initial) potential competitors/customers and conduct a detailed technical analysis. Since the technology is still in its early stage, conducting a full market assessment would be difficult, but conducting an initial market analysis and potential customers/competitors is crucial to understanding its value.

After the initial assessment of the market and improving the technology readiness level (TRL)[6], the following steps are crucial in successfully carrying out the technology commercialization process. The next steps are to prepare for commercialization by estimating the market size, confirming the commercial interest, establishing a strong business case/market strategy/formal business plan, and having a financial plan. These steps are essential because commercialization heavily relies on the business case.

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[6] A metrics that was created by NASA is used to assess the maturity of technology, but it does not indicate whether that technology will be successfully developed into a system or a product [Lee et al. (2011); NASA2012]. The metrics have 1 to 9 levels, in which levels 1~2 denote the basic technology research, levels 2~3 denote research to prove feasibility, levels 3~5 denote the technology development stage. Levels 5~6 denote the technology demonstration stage, and levels 6~8 denote the system/subsystem development stage. Finally, levels 8~9 denote the system test and operations stage (National Aeronautics and Space Administration (NASA), 2012).

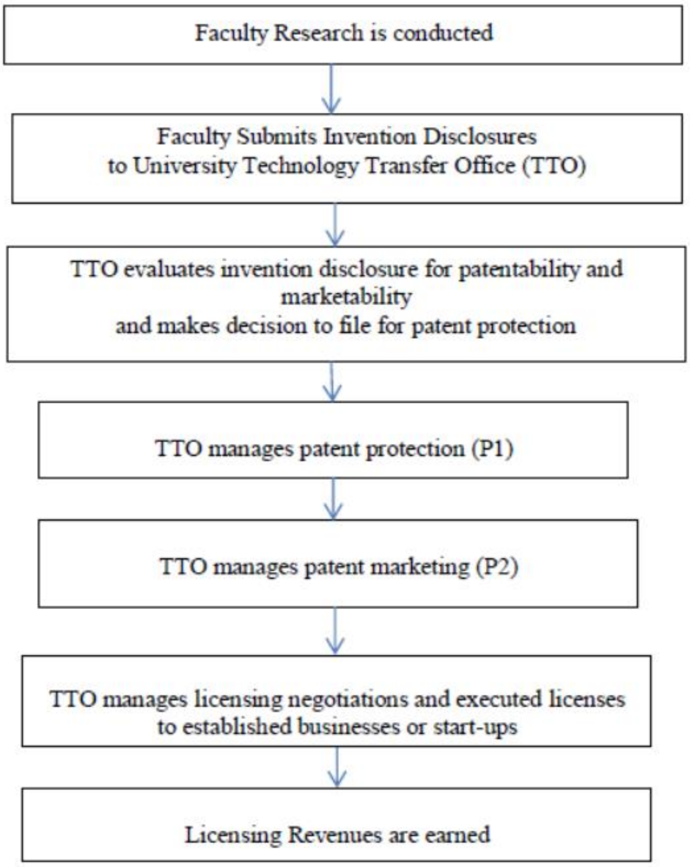
Gardner et al. (2004) highlighted that technology commercialization is a long and iterative process, and only one to two percent of all disclosed innovations had successful commercialization results. However, despite the low success rate of technology commercialization, the authors found true tangible benefits to the North American economy, such as an increased number of employees hired by small businesses and increased funds to support basic research.

Hamilton (2015) examined the TTOs and their lack of licensing revenues between 2005 and 2011 and proposed a conceptual model for the university TTO information processing system. The author found that the TTO staff focused more on intellectual property protection than patent licensing and marketing. Thus, the university TTO information processing system's conceptual model would help university TTOs shift their attention from patent protection to patent marketing and licensing.

Figure 2 shows Hamilton's supply chain network of university technology transfer (Hamilton, 2017).

Figure 2
Conceptual Model for University Tech Transfer Information Processing

1952).



Source. Hamilton (2015)

To protect the transferred technology and the inventors, a "March-in rights," also known as the diligence clause, are typically included in the licensing agreement to track the licensee's effort to commercialize the technology (Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, 1994; United States Code, 1952). The diligence clause is the most "controversial" provision of the Bayh-Dole Act (Bloch, 2015). The provision allows a federal agency to ignore the exclusivity of a license and grant additional licenses if the "contractor or assignee has not taken, or is not expected to take within a reasonable time, effective steps to achieve practical application of the subject invention" (United States Code, 1952).

2.3.3 Concept of University-Industry Collaboration and Transferring to Economy

In the knowledge-based society, the universities now play a bigger role than just educating the students; some have extended their roles and become "entrepreneurial universities" themselves to license their inventions and collaborate with companies to bring a bigger impact to the growing knowledge. This collaboration activity is known as University-Industry Collaboration (UIC). UIC research has a long history, but recently, there has been increased collaboration in countries like the United States and South Korea (Ankrah & Al-Tabbaa, 2015). UIC is perceived as a vehicle to enhance innovation through knowledge transfer and sharing between academia and industry. Han (2017) wrote that patenting new technologies through UIC is the first step in technology commercialization. According to Ankrah and Al-Tabbaa (2015), there have been many pressures for both universities and industries to be economic growth engines to stimulate innovation and economic competition. Therefore, UIC is a key activity as the main outcomes include research collaboration, intellectual property rights (patents and licenses), startup ventures, spinoff companies, promotion of effective university-industry relations, and better exploitation of university knowledge in relationship with the industry. (Gogan & Ivascu, 2014; Jaiya, 2010). UIC's major advantage is that transferring a technology brings economic advantages by licensing technology/inventions from universities to industries.

The government invests in research to create a reservoir of knowledge that can create new industries, companies/jobs, and methods to be more efficient, eventually earning taxes from these newly created workplaces. According to the National Science Board (2020), the federal funding for academic R&D expenditure has continuously increased since the 1980s, since the enactment of the Bayh-Dole Act However, support for other sectors and non-profit organizations fluctuated. In addition to the United States, other countries like Japan and the

European Union are interested in UIC activities since it positively influences universities and industries. Ankrah and AL-Tabbaa (2015) wrote that industries face pressures to produce rapid technology changes, shorter product life cycles, and global competition.

In contrast, universities face pressure to be involved in new knowledge with the shortage of funds. Through UIC activities, universities can receive an additional source of funds, build a research endowment, and receive a rich source of new ideas and technology and cheaper to license than to acquire small businesses (Jaiya, 2010). It is not easy to have a successful UIC activity since universities and industries have two different value systems. However, it is easier for both actors to conclude a common interest.

The industry sector's main value is making profits with continuous product R&D ideas. The advantages of the industry sector are their knowledge for profit, their entrepreneur mindset, feel for management, confidentiality, and limited public disclosure to help protect inventions. On the other hand, the universities' central values are teaching, researching, serving, and contributing to economic development. The advantages of universities are their knowledge bank, open discourse, and academic freedom. Universities and industries need to collaborate to commercialize new and useful technologies (Jaiya, 2010).

2.3.4 Success Factors in Technology Transfer and Commercialization

Technology transfer researches are conducted in many levels; for national level, there were researches that assessed different government support programs that assist technology transfers as an exploratory study using 1222 SMEs' data (Park & Chang, 2016), used cross-nation panel data to estimate the direct and indirect impact of intellectual property rights on R&D development and industry value added (Woo et al., 2015), comparing technology transfer systems in two countries (Schmoch et al., 1997) or even national policy level (Bozeman, 2000); for industry level, there were researches that used a firm as a case study to assess their technology transfer model (Amesse & Cohendet, 2001), assessed different technology transfer and commercialization models for transfer leaders (Nevens, 1990a), offered two model frameworks for technology commercialization (Amadi-Echendu & Rasetlola, 2011) and compared different case studies to understand success and failure factors of commercialization (Kim et al., 2012); for individual level, Perel (2007) conducted a study to analyze how personality attributes impacted the technology commercialization using attitude and Myer-Briggs tests to 69 doctorates working in firms.

Siegel et al. (2003) conducted a study to improve UIC's effectiveness by identifying factors and barriers to enhancing university-industry technology transfer. The authors stated that universities need to have organizational and managerial behaviors, improve staff training in TTOs, devote additional resources to technology transfer, encourage informal relationships and networks, and design flexible technology transfer policies to enhance technology transfer activities.

Furthermore, Friedman and Silberman (2003) emphasized the importance of inventors and incentives/royalties to successful university technology transfer. In addition, the authors concluded that greater rewards for faculty involvement in technology transfer, location of the university in a region with a concentration of high technology firms, a clear university mission in support of technology transfer, and the experience of the university's technology transfer office are all success factors to university technology transfer.

Table 3 summarizes the different factors that have been identified in the past literature. While many of the studies highlighted that top management support, speed to market, effective internal communication, and product/technology advantage were all positively related to a commercial process's success. On the other hand, the uncertainty of the market hurts the success of a commercialization activity. In addition, factors such as the firm size and the strength of the market competition showed different results. One reason might be the difference in culture and region in which the study was conducted (Guerrero & Urbano, 2019).

Table 3
Success and Failure Factors Identified in the Past Literature

Factor Classification	Details	Measurement Techniques	Relationship to TT/TC	Source
Organizational Factors	Company Features	Size of the enterprise (Number of employees)	Positive	(Kim & Shin, 2017; Korean Federation of SMEs (KBIZ), 2013)
		Top/Senior management support	Positive	(Montoya-Weiss & Calantone, 1994; Henard & Szymanski, 2001; Van Der Panne et al., 2003; Kim & Shin, 2017)
		Age of enterprise	Positive	(Kim & Shin, 2017; KBIZ, 2013)
		Experience in working with academia	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013; Van Der Panne et al., 2003)
		Confidence in results	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013)
		Absorptive capacity	Positive	(Barbolla & Corredera, 2009; KBIZ, 2013; Pertuze et al., 2010; Schofield, 2013)
		Traditional measures of a firm's performance (ROI, Level and growth of sales, profit)	Positive	(Derakhshani, 1984)
		Effectiveness of internal communication	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Sung & Gibson, 2005)
		Sensitive to change in the customer and environment	Positive	(KBIZ, 2013)
	University and GRI Features	Level of general/specific know-how	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013)

		Setting up TTO or Committee	Positive	(Sung & Gibson, 2005)
		Researchers motivation	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Sung & Gibson, 2005)
		Incentives and reward structure	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013)
		Strong leadership	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013)
		Experience in working with industry	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013)
	Company CEO's Characteristics	Executive's personality (Management Competency Factor; Executive Values; Motivations)	Positive	(Van Der Panne et al., 2003; KBIZ, 2013)
		Executive's experience (Marketing Experience; HR Capabilities; Management and Business Skills)	Positive	(Van Der Panne et al., 2003; KBIZ, 2013)
Innovation Factors	Technology Innovative Activities	Number of R&D Personnel	Positive	(Henard & Szymanski, 2001; KBIZ, 2013)
		R&D Investment	Positive	(KBIZ, 2013)
		Equivocality (Degree of Concreteness of Transferred Knowledge and Technology]	Positive	(Sung & Gibson, 2005)
		Technology Commercialization	Positive	(Kim & Shin, 2017; KBIZ, 2013)

		Capacity		
		Innovation Management Skills	Positive	(KBIZ, 2013)
		Number of Product Innovations	Positive	(KBIZ, 2013)
		Speed to market	Positive	(KBIZ, 2013; Montoya-Weiss & Calantone, 1994; Van Der Panne et al., 2003)
		Technology maturity and Readiness Level	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Park et al., 2013)
		Intellectual Property	Positive	(Ham & Ko, 2016; KBIZ, 2013)
		Product/Technology Advantage	Positive	(Henard & Szymanski, 2001; Montoya-Weiss & Calantone, 1994; Van Der Panne et al., 2003)
	Collaboration Activities	External Collaboration Experience	Positive	(Araújo & Teixeira, 2014 KBIZ, 2013)
		Size of Collaboration Activity	Positive	(KBIZ, 2013)
		Established planning and coordination	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013)
		Shared vision	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013)
		Clarity of role and responsibilities	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013)
		Long-term relationship	Positive	(Barbolla & Corredera, 2009; Pertuze et al., 2010; Schofield, 2013)
Environmental Factors	Market Environment	Strength of Market Competition	Barely Any Relation	(Kim & Shin, 2017)

		Positive	(Henard & Szymanski, 2001; KBIZ, 2013; Montoya-Weiss & Calantone, 1994)
	Uncertainty in the Market	Negative	(Kim & Shin, 2017)
	Market Potential and Size	Positive	(Derakhshani, 1984; Henard & Szymanski, 2001; KBIZ, 2013)
	Industrial Properties (Growth stage, industry type, R&D Intensity)	Positive	(KBIZ, 2013)
Conglomerate Dependence	Subcontract with Conglomerates	Positive	(KBIZ, 2013)
Location	Geographical Proximity	Positive	(House & Silveria e Silva, 2014; KBIZ, 2013; Sung & Gibson, 2005)
Government Policy	Size of Technology Development Funding	Positive	(House & Silveria e Silva, 2014; KBIZ, 2013)
	Size of Private Funds	Positive	(KBIZ, 2013)
	Presence of Government Funding	Positive	(KBIZ, 2013)
	Environment Regulation Intensity	Barely Any Relation	(Kim & Shin, 2017)
	Intellectual Property Protection Intensity	Barely Any Relation	(Kim & Shin, 2017)

2.4 Technology Transfer and Commercialization Ecosystem in Korea

There are two types of technology transfer in Korea; 1) Private Firm - Private Firm transfer (noted as the Private Technology Transfer), and 2) Public Organization (University or GRI) - Private Firm Transfer (noted as the Public Technology Transfer) (Park & Park, 2017). The private technology transfer is hard to evaluate and track. This is because most private firms develop technology to commercialize for themselves. Thus, the frequency of a private technology transfer is low; moreover, a private technology transfer's success relies on the developed technology's profitability. On the other hand, unlike private technology transfer, public technology transfer is far easier to track since most of the technology developed in public organizations is created for technology transfer to the private sector. In addition, Park and Park (2017) noted that the idea of direct commercialization is being introduced in public organizations by creating spinoffs. Still, technology transfer has been far more appealing to public organizations.

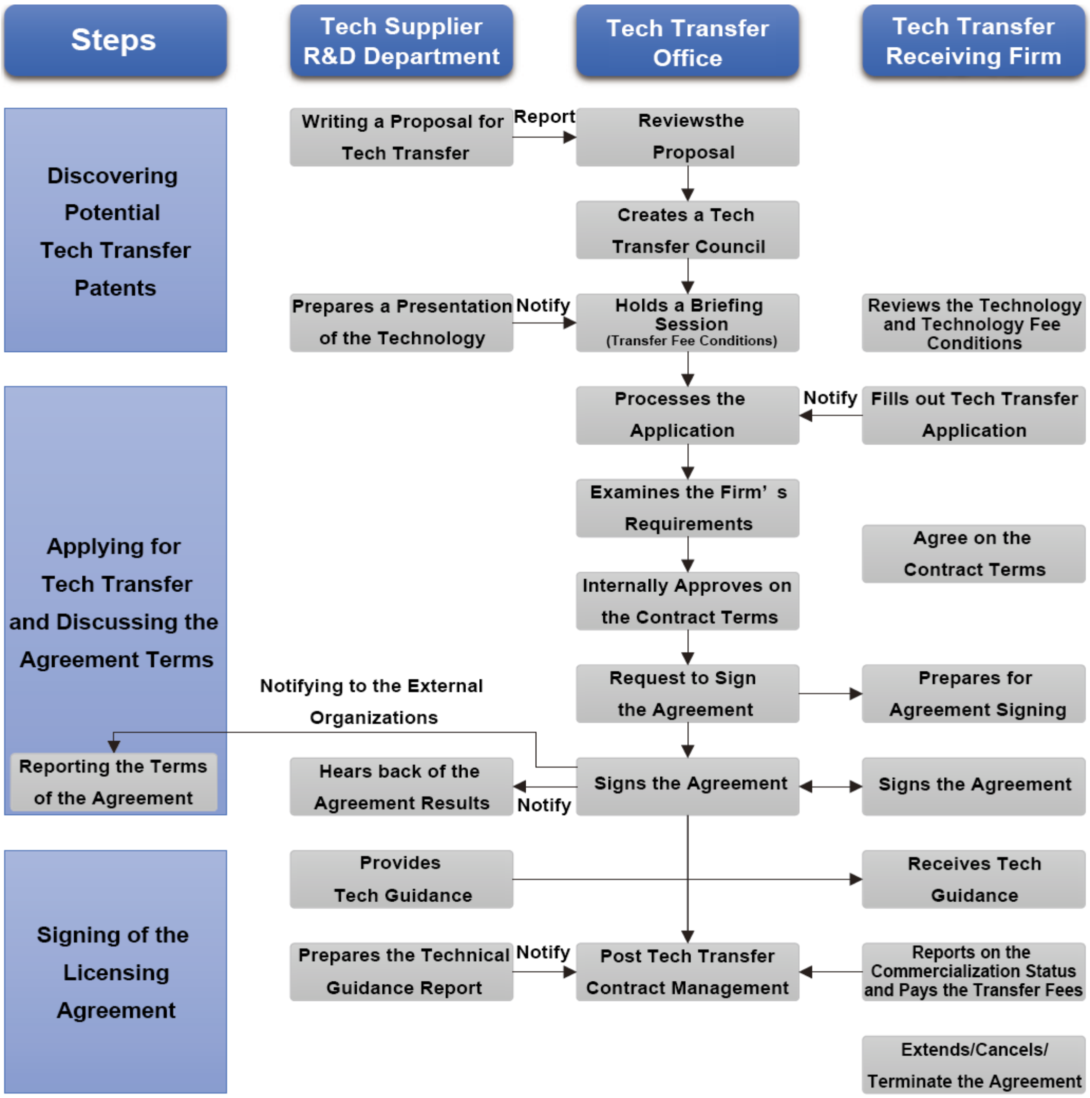
According to the Technology Transfer and Commercialization Promotion Act, technology transfer is given priority to firms carrying out their production and sales activities in Korea. The firm that wishes to receive the technology carries out the technology transfer process. In Korea, the technology transfer, commonly noted as public research institute (university and GRI) technology transfer, is carried out by changing technology ownership or licensing, making most technology transfer cases (Park & Park, 2017).

When technology transfer is agreed upon, the university/GRI and the firm agree upon the licensing agreement's details. However, there are different regulations on licensing and different technology fee methods. For example, the MSIT and the Ministry of Trade, Industry, and Energy (MOTIE) have policies on how government R&D funds should be spent.

After the licensing agreement has been signed, the university or the GRI works with the technology transfer department or a TTO to provide the necessary documents and information about the technology/patent to the receiving firm, who reports back on their commercialization process and results. The receiving firm can either terminate or extend the licensing agreement (Park & Park, 2017). Figure 3 shows the transfer and commercialization of public research institutes to firms.

Figure 3

Simple flowchart of technology transfer to commercialization



Source. Min et al. (2019)

Note. Originally in Korean, translated into English.

2.4.1 Technology Transfer and Commercialization Policies and Strategies in Korea

In January 2000, the Technology Transfer and Commercialization Promotion Act was enacted under the jurisdiction of the Trade, Industry, Energy, SMEs, and Startups Committee. The act promotes technology transfer to the private sector and commercialization of technologies developed at public research institutes and supports smooth transaction, transfer, and commercialization of technologies developed in the private sector (Lee & Kim, 2013; Park & Park, 2017; Yang, 2011). Since enacting the act, Korea has promoted government-led technology transfer and commercialization, promoting policies and establishing various agencies and institutions (Yang, 2011). Korea Technology Transfer Center (KTTC) was first established in 2000 to promote Korea's technology transfer and commercialization activities (Kim, 2001). There were no technology transfer cases during the first year, but in 2005, 256 technology transfer and commercialization consulting cases occurred (Kim, 2001). The government and policies formed an infrastructure to foster technology transfer, and various agents like university TTOs and technology trading/evaluation institutions have been fostered. As a result, researchers, firms, and the general public are interested in fostering the technology transfer and commercialization ecosystem and improving national competitiveness (Yang, 2011).

The effort to promote technology transfer and commercialization has been implemented at various levels (Yang, 2011). The technology transfer and commercialization policies have centered on technology transaction, assessment, and public sector commercialization. The policies have been created and centered around the MOTIE. The MOTIE set up policy goals and promotion goals for technology transfer and established a promotion plan. The Technology

Transfer and Commercialization Promotion Plan are updated every three years[7] under Article 5 of the Technology Transfer and Commercialization Promotion Act (Kim & Kim, 2019). In addition, the MSIT's National R&D Project Management and MOTIE's "Operational Guidelines for Knowledge Economy Technology Innovation Projects" have different regulations on technology ownership (Lee & Kim, 2013).

2.4.2 Technology Transfer and Commercialization Status in Korea

As defined by the patent licensing royalties, the Korean government's technology transfer performance is less than the United States (Lee, 2013). According to Park and Park (2017), the total technology transfer licensing revenue in 2013 in Korea was only 4.5% of the United States licensing revenue. Compared to the United States' research productivity of 4.31%, Korea was only 1.36%. Furthermore, Hyun et al. (2015) highlighted that 70% of the public technologies are not transferred, and only 15% of the transferred technologies are commercialized in South Korea.

In 2019, the total technology transfer licensing revenue reached the highest record of 227.3 billion KRW, which was an increase of 19.8% from 2018; however, the cost to transfer and commercialize a technology, maintain patents, and other administrative fees were five times of the licensing revenue (Ministry of Trade, Industry, and Energy (MOTIE), 2020). Table 4 shows the breakdown of technology transfer activity by the supplying institute and the yearly technology transfer rate, defined as the ratio of the number of technology transfer cases and the total number of the newly developed technology in that particular year.

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[7] The initial strategic plan was a five-year plan, and since 2006, the plan has been updated every three years.

Table 4

Breakdown of Technology Transfer Activity by the Supplying Institute and the Yearly Technology Transfer Rate

Classification		Newly Developed Technology	Technology Transfer Cases	Technology Transfer Rate (%)[8]
Total		32046	11002	34.33
GRI	Government-funded RI[9]	6813	3415	50.13
	Korea RI[10]	2768	534	19.29
	Industrial Technology RI	1472	185	12.57
	National Public RI	987	930	94.22
	Other Public RI	1419	267	18.82
	Total	13459	5331	39.61
Uni.	Public	6846	1778	25.97
	Private	11741	3893	33.16
	Total	18587	5671	30.51

*RI denotes Research Institutes

Source. Korea Institute of Intellectual Property (KIIP) (2019)

Similarly, Table 5 shows the changes in the technology transfer rate and the R&D expenditure per GDP and Patent information from 2011 to 2018. In conclusion, the Korean government has increased the funds to support public research institutes. This has increased the number of technology transfers from public research institutes to SMEs and commercialization activities. However, increased technology transfers have not resulted in royalty licensing revenues.

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[8] Calculated as the ratio of the number of technology transfer cases and the number of newly developed technology

[9] Those part of the "National Research Council of Science & Technology (NST)"

[10] Those specializing in a particular area of scientific R&D

Table 5
Changes in the Technology Transfer Rate, R&D Expenditure Per GDP, and Patent Information Per Year (2011-2018)

Year	R&D Budget Per GDP[11]	Patent Applied[12]	Patent Register[13]	Technology Transfer Rate[14]
2018	4.810	209992	119012	34.3
2017	4.553	204775	120662	37.9
2016	4.227	208830	108875	38.0
2015	4.217	213694	101873	38.6
2014	4.289	210292	129786	31.7
2013	4.149	204589	127330	31.2
2012	4.026	188915	113467	27.
2011	3.744	178924	94720	26.0

2.5 Electric Vehicles and the Industry

2.5.1 Definitions of EVs and Overview of the EV Industry

The definition of EVs depends on each country and can include battery electric vehicles (BEV[15]), plug-in hybrid electric vehicles (PHEV[16]), fuel cell electric vehicles (FCEV[17]) and hybrid electric vehicles (HEV[18]) (International Energy Agency (IEA), 2021). The dissertation

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[11] The World Bank (2020)

[12] Ministry of the Interior and Safety (MOIS) (2019)

[13] Ministry of the Interior and Safety (MOIS) (2019)

[14] Korea Institute of Intellectual Property (KIIP) (2019)

[15] Battery powered, fully EV

[16] Hybrid of EV and Combustion Engine. First runs on fully EV power then switches to combustion engine (petrol or diesel) when the EV battery is depleted (IEA, 2021)

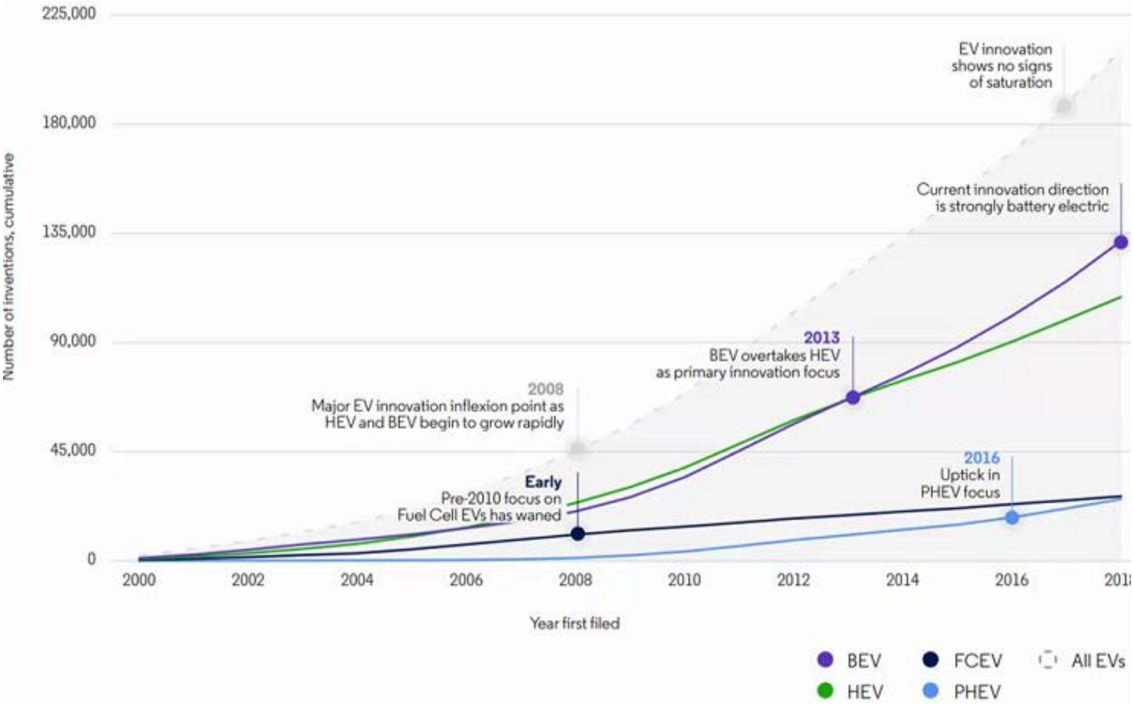
[17] Hydrogen powered fuel cell that powers the electric motor (IEA, 2021)

[18] Combination of electric propulsion system and ICE (IEA, 2021)

defines EVs as BEVs and PHEVs because they both require charging. The dissertation defines EVs as BEVs and PHEVs because both use batteries and requires charging.

Figure 4 shows how each EV type developed between 2000 and 2018. It was a fairly close race between BEV and HEV types until 2013, when BEV started to accelerate forward (Clarivate, 2021). Furthermore, according to Clarivate (2021), EV innovation continued to develop and showed "no signs of saturation" in 2018.

Figure 4
The Development status of different EV types from 2000 to 2018

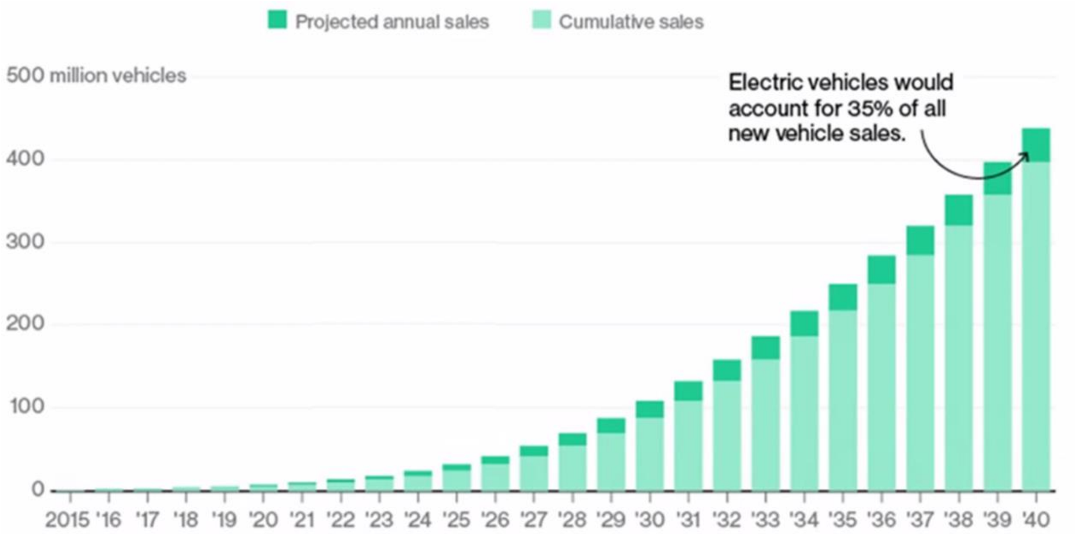


Source. *Clarivate (2021)*

Kearney (2016), a global consulting firm, reported the potential EV market to grow up to several hundreds of million dollars by 2030. Engel et al. (2018) also reported that about 120 million electric vehicles would be operated by 2030. Emura et al. (2014) stated that EVs help lower carbon dioxide levels are a good substitute for fossil fuels, and connect to the energy and social infrastructure. Finally, Martin et al. (2018) highlighted several key benefits of deploying EVs. First, with increased EVs and optimized charging technology, the air quality would be improved. Second, EVs can amplify the potential of smart charging and its integration with the smart grid. Third, when EVs become more affordable, they will enhance the energy management of the batteries. Since the electric fee is different by the hour, smart charging and energy management can create a charging schedule to improve efficiency.

EV competition is still growing in 2022. Bloomberg New Energy Finance (BNEF) (2022) reported that investment in the electric transportation sector has risen by a compound annual growth of 48% since 2014. Naughton and Ludlow (2022) reported that Ford Motor Co. plans to invest up to $20 billion in building EVs. In addition, GM is spending $6.6 billion on EV plant investment through 2024 to 1) increase electric pickup truck production and 2) build a new EV battery cell plant in hopes of dethroning Tesla in the EV industry (Wayland, 2022). Furthermore, South Korea’s LG Energy Solution announced its plans to invest $5.3 billion in 2022 to expand its manufacturing capacity as its major partnerships in the automobile industry are planning to introduce new EV lineups (Holman, 2022). Tesla also announced its plans to create a Tesla Gigafactory in Shanghai, China, to achieve a production capacity of 1 million EVs per year (Lambert, 2022). According to Sodré (2021), the total number of electric vehicle sales worldwide will exceed 400 million EVs by 2040, and EVs will account for 35% of all new vehicle sales in 2040. Figure 5 shows the projected sales of electric vehicles worldwide.

Figure 5
Projected sales of electric vehicles worldwide



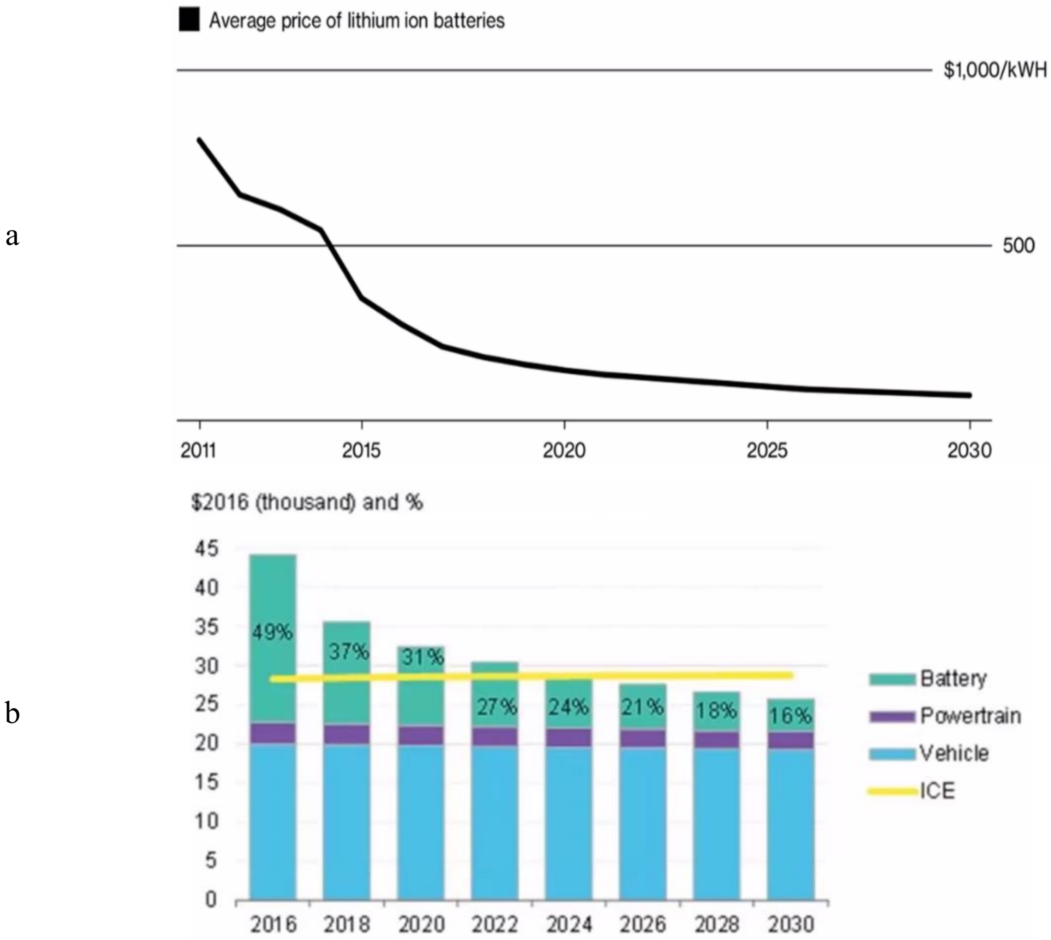
Source. *Sodré (2021)*

Sodré (2021) highlighted several decisive factors for the market penetration of EVs. The first factor is the specific geographical and energy market characteristics of countries. EVs produce zero direct emissions and help improve air quality, especially in urban areas, where cars are far more than in rural areas. According to the Office of Energy Efficiency & Renewable Energy in the United States (2021), EVs produce fewer life cycle emissions than ICE cars, and the amount of the emissions of the EVS depends on the electricity mix varies by geographical location. In addition, if a country wishes to increase the number of EVs, a plan to stop the electric power grid from collapsing due to vehicle electrification is needed.

The second factor is fuel and EV prices. Sodré (2021) examined the change in the price breakdown of a medium-sized EV from 2016 to 2030 and highlighted that the price of the powertrain and vehicle does not change over the period, but only the price for the battery changes. After a steep decrease in the price in 2015, it is projected to decrease slower after 2020. Figure 6 examines the price of lithium-ion batteries and the EV price breakdown. In addition, the yellow line represents the average cost of ICE vehicles in 2016. According to

Figure 6(b), drivers should wait until 2026 for EVs to have the price advantage of ICE vehicles. However, the figure does not consider the federal tax credit and government incentives for purchasing an EV.

Figure 6
The projected average price of lithium-ion batteries and the EV Price Breakdown

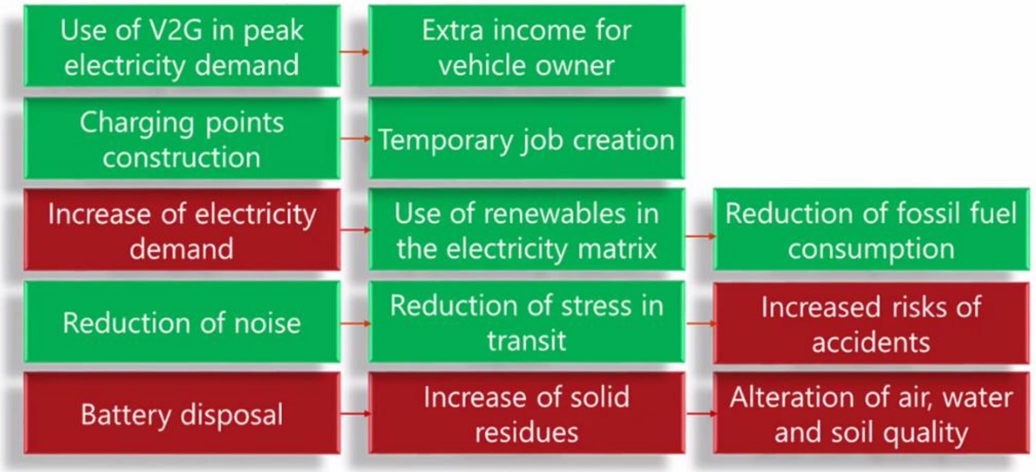


Source. Sodré (2021)

The third factor is the tax exemption and incentives. Many governments worldwide support the adoption of EVs by providing purchase rebates (to offset the price difference between EVs and ICE vehicles), tax exemption, and tax credits. The fourth factor is the social behavior of drivers. According to Paparoidamis and Tran (2019), customer acceptance of eco-friendly products remains a problem despite the growing interest in eco-friendly products. The authors emphasized the need to understand customers' decision-making better when purchasing eco-friendly products, especially automobiles. The fifth factor is the possibility of implementing Vehicle-to-Grid (V2G). V2G is a technology that enables EVs to communicate with the grid by charging or discharging the battery. According to Virta (2021a), V2G technology enables the drivers to use the EV battery ten times more efficiently when compared to unidirectional charging (charging station to EVs).

The last factor is the standardization of components and systems. According to Gordon (2021), there are three different EV charging connectors. In addition, there are currently two different charging "networks," Tesla and the rest. However, an EV startup called Rivian, funded by major investors like Amazon is building its charging network consisting of 3,500 fast-charging stations. ICE vehicle drivers can stop by any gas stations to fill up, but this might not be the case for EVs. New EV manufacturers building their charging network only complicates the charging system. Figure 7 shows a flowchart of EV feasibilities presented by Sodré (2021). The green boxes represent actions that create positive results. For example, by using V2G technology at peak electricity demand, EV owners can sell the energy stored in the EV battery to make extra income (electricity is sold at a higher price). However, there are also negative results. For example, with the increase of EVs, there is a greater need for electricity demand. In addition, when EV batteries reach their limit, they are disposed into the ground. The disposal of batteries increases solid residues, which causes air and water pollution and alters soil quality.

Figure 7
EV Feasibility Flowchart



Source. Sodré (2021)

2.5.1.1 EV Adoption Comparison

As stated in Chapter 1, South Korea had only 2.3% of the EV share in 2018 (Yoon, 2022). With the growing importance of a green climate and a sustainable environment, the South Korean government announced its plans to increase the market share of EVs in the sales of new vehicles to 33% by 2030 (Yoon, 2022). In 2021, South Korea was the seventh-largest country in cumulated EV sales between 2020 to 2021, which increased by 96% in one year. (Park, 2021a). However, despite the increased EV sales, the EV share is only 5.5%.

In the United States, three out of ten adults state that they know a lot about EVs, and 53% of them would consider purchasing an EV in the future, while 39% say they would not consider purchasing one soon (Spencer and Funk, 2021). 51% of US adults are opposed to the phase-out production of internal combustion engine (ICE) vehicles (Tyson et al., 2021). On the other hand, in Europe, the sales of diesel cars and EVs are similar, showing how Europeans are starting to embrace EVs. The European dealership reported that 176,000 EVs were sold in December 2021, and electrified passengers' vehicles in Denmark surpassed the 50% share

(Fortuna, 2022). Also, Norway is the world leader in EV transition, with more than 91% share of automobile registration in 2021 (Holland, 2021).

2.5.1.2 Reasons for EV Resistance

The idea of EVs became practical in the 1870s and started to gain popularity in 1899 (Department of Energy (DOE), 2022). In 1901, Thomas Edison thought EVs were excellent for transportation and thus worked on building a better battery. However, since the 1920s, cheaper crude oil has led to the disappearance of EVs in the United States (Doe, 2022). In 2006, Tesla Motors announced its luxury EV, and since then, other automakers have joined the industry. However, while EVs have many advantages over internal combustion engine (ICE) vehicles, such as higher energy transition efficiency and reducing climate change, the advantages have not been enough to persuade consumers to transition to EVs (Li et al., 2017).

Tsai et al. (2010) found that technology resistance is due to innovation-related perceived risks. Furthermore, Priessner et al. (2018) examined the effect of socio-demographic, psychological variables and EV policy incentives on EV adoption in Austria. The authors found that a household with no cars favors EVs, while a household with more than one car is not an indicator for early EV adoption. Interestingly, the authors found no significance in potential adopters and early adopters in terms of pro-technological attitudes. In addition, the authors found that a person living in a region with no subsidies for EVs is 63% more likely to be a potential EV user than an early adopter and showed no differences between early EV adopters and non-adopters.

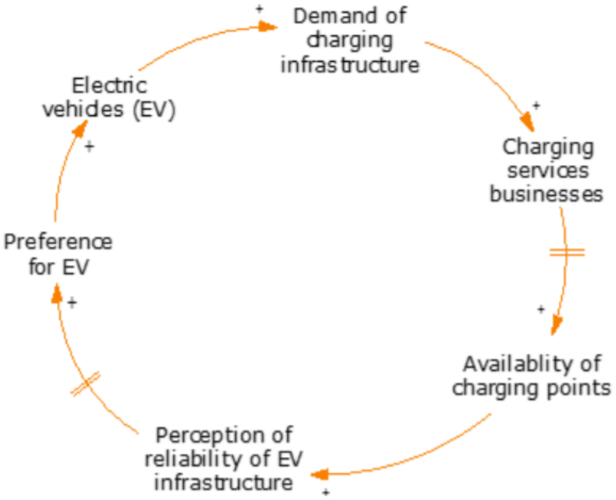
Jeon et al. (2012) compared hybrid electric vehicle (HEV) adoption in South Korea and China and found that perceived financial risk for HEV adoption was higher in China, while perceived psychological risk was higher in Korea. Psychological risk often relates to the lack of driving range and insufficient charging infrastructure (Viola, 2021). Egbue & Song (2012) and Hackbarth & Madlener (2016) found the driving range of EVs to be one of the major barriers to EV adoption. The driving range for EVs has increased where consumers are satisfied with short-distance trips but not for long-distance trips (Tamor et al., 2015). Furthermore, long charging time and insufficient charging infrastructure are major barriers to EV adoption since it is difficult to radically reduce the charging time (Li et al., 2017). Jensen et al. (2013) stated that charging at the workplace and the number and location of charging stations in the public domain are very important.

2.5.2 EV Charging Stations and Charging Infrastructure

According to Holland (2013), building a “robust public fueling network of charging stations” is the key to a successful EV market, but it has been generally viewed as a chicken-versus-egg dilemma. EV potential consumers would prefer to have charging infrastructure settled before deciding whether to purchase an EV, while the government would prefer to have EV consumers purchase their EVs before deciding to invest in charging infrastructure. Aria-Gavira et al. (2021) explain the dilemma as the reinforcement loop between EV demand and charging infrastructure (Figure 8). The authors stated that the adoption of EVs depends on the population that prefers EVs over ICE vehicles, and more EVs require more charging stations. Because increasing the number of charging stations requires heavy investment and is time-consuming, researchers are providing super fast-charging stations that can fully charge the battery in just ten minutes (Messer, 2019) or use wireless charging (Mude, 2018).

Figure 8

Reinforcement loop between demand for EVs and Charging infrastructure



Source. Arias-Gaviria et al. (2021)

Therefore, Delacrétaz et al. (2020) examined the effect of charging infrastructure on EV adoption. The authors found that while the charging infrastructure initially had little impact on EV adoption, the effect becomes more positive over time. They also found that the more charging stations there are, the greater the increase in EV demand. Furthermore, Kwon et al. (2018) surveyed EV owners in the Jeju region of South Korea. The authors found that Jeju EV owners felt uncomfortable charging their EVs but were willing to pay more for charging time reduction. On the other hand, Kim and Heo (2019) examined the key drivers for EV adoption in South Korea and found no clear relationship between EV diffusion and EV charging infrastructure. The authors assumed that this result might be that current charging is done by slow charging (level-2 charging) and claimed that if the Korean government pushes for public chargers in the current state, there will be a small effect on EV adoption compared to the heavy investment in installing level-2 chargers.

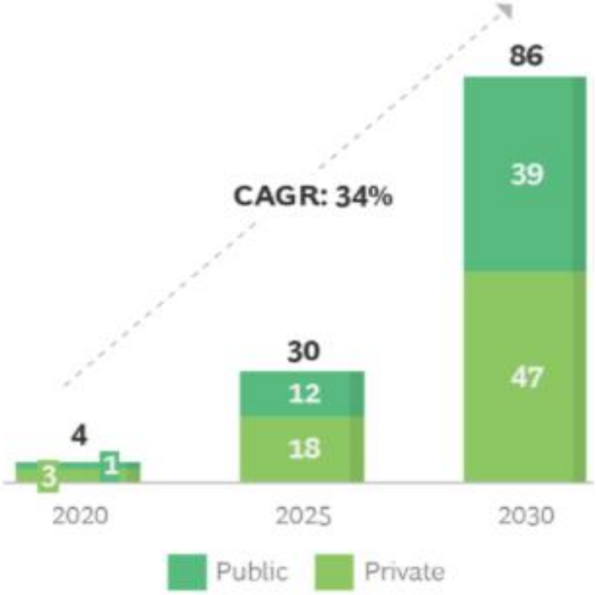
Figure 9 compares the cumulative EV sales, the number of public charging stations, and the ratio between them in the United States. Interestingly, the ratio between the cumulative EV sales and the number of public charging stations continues to grow, showing how public charging stations are installed slower than consumers purchasing EVs. One reason for the low installation of public charging stations may be because two-thirds of electricity demand for EV charging has been private, meaning the charging has been done at home or workplaces in Europe (Hagenmaier et al., 2021). According to Hagenmaier et al. (2021), the electricity demand for public charging will be close to that of private charging by 2030, as shown in

Figure 10.

Figure 9
Cumulative EV sales vs. Number of Public Charging Stations in the US

Source. EV Adoption (2020)

Figure 10
The proportion of electricity demand of private and public charging



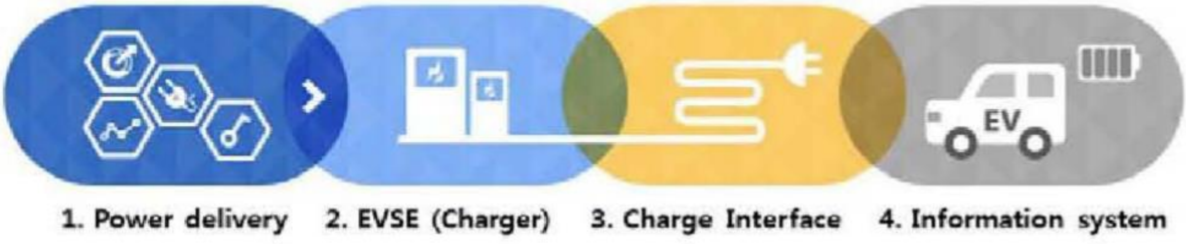
Source. Hagenmaier et al. (2021)
Note. CAGR refers to compound annual growth

EV charging networks can be the pivot for smart city services (Cheryl Martin & Tricoire, 2018). Ghosh (2020) highlighted that EVs' essential components are storage systems, charging stations, and power electronics. The grid and renewable energy systems can power EV charging, but EVs' potential is debatable if the EVs' power comes from fossil fuels (Ghosh, 2020). Furthermore, Potdar et al. (2018) stated that while EV adoption is becoming a popular topic, deployment has challenges. One of the challenges is the lack of charging infrastructure. Engel et al. (2018) reported that the EV industry would require about 40 million charging stations in the United States, Europe, and China and estimated a cumulative 50 billion dollars of investment through 2030.

Electric vehicles can be charged through 1) residential charging stations, 2) public charging stations in public parking lots, malls, or centers, 3) public charging stations in between long-distance trips, and 4) battery swapping (Bhatti et al., 2016). In addition, due to the high sensitivity of charge and discharge activity in some battery types, a battery or energy management system is needed (Aruna & Vasan, 2019; Bhatti et al., 2016). The energy management system (EMS) is a control system within the electric vehicle that controls the flow of power, manages the charging and discharging of the battery, and functions of other parts of the EV (Aruna & Vasan, 2019).

The Electric Vehicle Charging Infrastructure (EVCI) is an umbrella term that describes related hardware and software to charge the electric vehicle's battery (Park, 2019), and it can be divided into four areas, as shown in Figure 11. The first area is power delivery, which deals with the transmission and distribution of electricity, power supply equipment, wiring, and other necessary infrastructure to transfer electricity into the vehicle through the charger. Second, Electric Vehicle Supply Equipment (EVSE) or the charger refers to the interface to safely transfer the electricity from the grid, solar panels, or power suppliers to the EVs in the form of AC or DC power. Third, the charging interface refers to the cables, plugs, and wireless transmission pads to transfer the power into the vehicle. Finally, the information system refers to the operation interface of the charging systems and thus, includes plug types, location, and user information.

Figure 11
Four areas of Electric Vehicle Charging Infrastructure



Source. Park (2019)

There are three major types of charging methods. The first method is direct or plug-in charging, often the most common method. This method uses plugs that connect the charger to the EVs, like charging other electronic devices. There are three levels of plug-in charging, with DC fast charging being the fastest (Park, 2019). However, the drawback of this method is that manufacturers use different types of plugs, thus making the charging infrastructure complex. Tesla is the largest EV seller in the United States, and it is due to its network of "superchargers" (Plungis, 2019). Telsa boasts more than 1,533 stations and 13,000 individual stations worldwide and is expected to turn to "V3 chargers" that can charge up to 250 kW, or up to 75 miles of range, in just 5 minutes of charging (Plungis, 2019).

The second method is battery swapping. EV owners would be able to swap their low battery modules into fully charged ones in just 10 minutes, thus decreasing the waiting time (Park, 2019). Ample, a startup working with several EV manufacturers, built battery-swapping stations that can swap batteries in 15 minutes (Baldwin, 2021).

Finally, the third method is wireless charging. Despite the early stages of innovation, wireless charging is already available in some EV manufacturers, such as Nissan (Clarivate, 2021). Furthermore, EV companies and universities actively develop wireless charging and battery technologies. The first example is an EV company that developed a "pop-up" pavement charger that can be controlled through a smartphone application, and electrified roads have been tested for charging EVs on the go in Sweden (Clarivate, 2021). Another example is the Indiana Department of Transportation (INDOT) partnering with Purdue University to develop a dynamic wireless highway charging. According to INDOT (2021), the state of Indiana, known as Crossroads of America, wants to deliver infrastructure that can support the adoption of EVs and set the standard for affordable, sustainable and efficient transportation electrification.

The dissertation focuses on wireless charging because of the following reasons. First, plug-in charging offers limited charging due to the lack of EV charging stations. While super-fast charging is available in public, as stated in the previous section, most EV charging station is limited to charging one car at a time. Single chargers with multiple cables are in demand and are under development but may not be as efficient as charging one vehicle at a time. Second, battery swapping is available to the public in several locations. Tesla experimented with battery swapping in 2013, but the project disappeared as supercharger stations were available in 2016 (Kiefer, 2022). Finally, stationary contactless charging or even on-road wireless charging will remove the necessity of cables, eliminate range anxiety, and lead to automated driving (Mouli et al., 2017).

2.5.3 Different Types of EV Wireless Charging Technologies

Until 2018, the wireless power transmission market has been concentrated on smartphones and some smart devices (not EVs), and thus, the market size and growth have been less than its forecasted numbers (Kim et al., 2018). However, wireless power transmission has recently been applied to electric vehicles (Iqteit et al., 2021).

According to Valtchev et al. (2012), there are two different methods of wireless energy transmission and are differentiated by electromagnetic field propagation. The first method is the contactless near-field power transmission. Contactless Near-field power transmission is classified into capacitive coupling, magnetic inductive coupling, and magnetic resonant coupling. Capacitive coupling technology, which A. Rozin first patented in 1998, transfers energy between metal plates by oscillating in a high-frequency electric field (Valtech et al., 2012). This technology, however, is not applicable for EVs as it requires the electric field to reach extremely high intensity to reach the power level (Valtech et al., 2012).

The magnetic inductive (MI) coupling is used as the conventional method for wireless charging and has been made available to the market by numerous companies (Valtech et al., 2012). The magnetic inductive coupling method uses the magnetic induction phenomenon between the transmitting and receiving coils (Jun and Oh, 2019). An induction phenomenon is when a current flows in the primary coil to generate a magnetic field, and this change in the magnetic field creates a current in the secondary coil (Jun and Oh, 2019). The magnetic induction method has high technical maturity, is widely used in mobile phones due to its small module size, and can transmit power of several milliwatts (mW) to several tens of kilowatts (KW) within a few millimeters (mm) with an efficiency of 90%, is harmless to the human body and can be used underground and underwater (Jun and Oh, 2019). However, the transmission distance is only a few millimeters despite the advantages.

Magnetic resonance (MR) coupling is used by self-resonance characteristics between the transmitting and receiving resonators (Jun and Oh, 2019). Resonance occurs when the natural frequency determined by the inductance and coil value included in the circuit coincides with the frequency of the power source. Electromagnetic waves move from one medium to another and transmit power (Jun and Oh, 2019). According to Jun and Oh (2019), due to the resonance phenomenon, the magnetic resonance method can transmit power at a greater distance than the magnetic induction method, and the energy not transferred to the receiver is not radiated into the air but is absorbed back into the coil of the transmitter and has high efficiency. Currently, the magnetic resonance method has a transmission efficiency of about 90% at a distance of 1m and about 40% at a distance of 2m (Jun and Oh, 2019). In addition, the authors stated that the magnetic resonance coupling technology is at a stage where commercialization and standardization are possible but has a long charging duration.

The second method is the contactless far-field power transmission. Contactless far-field power transmission consists of laser-beamed power transmission and microwave power transmission. Laser-beamed power transmission uses a solar panel to transform laser beams into electricity (Valtchev et al., 2012). However, Valtchev et al. (2012) stated that this technology is far from efficient as most energy is lost during the transformation period. Nevertheless, this technology is currently being used in models and prototypes for specialized companies, such as LaserMotive, which is developing a space elevator (Valtchev et al., 2012). While interest in laser beamed power transmission has grown, as shown in recent studies (Rathod and Hughes, 2019; Triviño et al., 2021), the usability is limited mainly for military purposes due to the possibility of harmfulness to the human body (Kim et al., 2018).

The microwave method, or electromagnetic resonators, is a technology for transmitting power by radiating a microwave signal into the air through an antenna and is mainly used for long-distance power transmission (Kim et al., 2018). The microwave method, which can dramatically increase the power transmission distance, attracts attention to supplying power to multiple power receiving devices with one power transmitting device (Kim et al., 2019). However, like laser-beamed power transmission, microwaves may have a detrimental effect on the human body due to low power transmission efficiency and IEEE standards (Kim et al., 2019). The microwave method is currently capable of delivering several mW of power at several tens of kilometers with an efficiency of about 10 to 50% and is receiving positive reviews as a future technology because it can transmit power over a longer distance than magnetic induction and magnetic resonance methods (Kim et al., 2018). However, if there are any foreign or obstructing objects between the transmitter and receiver, there is a loss of efficiency (Kim et al., 2019). According to Kim et al. (2019), the microwave power transmission is suitable for military or space exploration applications that require little power. Table 6 summarizes the features of EVs' three major wireless charging technology.

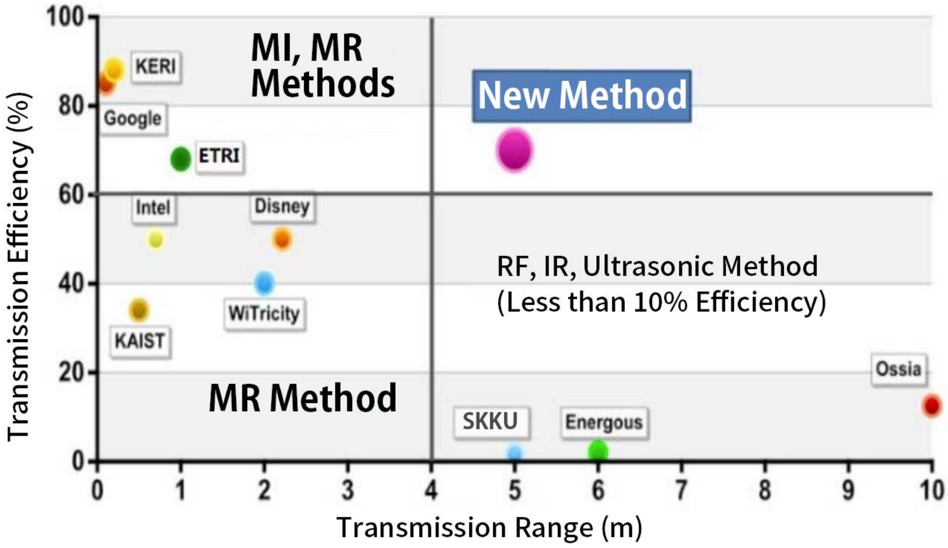
Table 6
Three methods of wireless charging

Features	Charging Methods		
	Magnetic Inductive (MI) Coupling	Magnetic Resonance (MR) Coupling	Microwave Power Transmission
Power	Several W to hundreds of kW	Up to several hundred W	Up to tens of kW
Transmission distance	Within several mm	Within 10m	Within several km
Efficiency	90%	90% within 1m 40% within 2m	10~50%
Advantages and Drawbacks	• High technical maturity • Widely used in mobile phones • Reduced module size • Harmless to the human body • It can be used underground and underwater	• The transmission distance is longer than the magnetic induction method so it can be widely applied to electric vehicles and various electronic devices. • Technology development for commercialization and standardization • Relatively long charging time	• Available with high output • Longer transmission distance compared to the other methods • The size of the transmission antenna is big and has low transmission efficiency • Potentially harmful to human beings

Source. Jun and Oh (2019)

Electronics and Telecommunications Research Institute (ETRI) compared their wireless power transmission technology to developed methods. Figure 12 shows the transmission efficiency and transmission range for each wireless power transmission method. For example, MI and MR methods have excellent efficiency, but the transmission range is extremely limited. On the other hand, the laser method can transmit at a long distance, but as stated above, it comes with health-related problems for the human body. The RF method is perfect for medium to long-distance transmission but is limited to low-power sensors and batteries due to electromagnetic wave regulations (Kim et al., 2018). Therefore, a new method to expand wireless power transmission to more diverse applications with higher efficiency and range is being developed (Kim et al., 2018).

Figure 12
Transmission Range and Efficiency of different wireless power transmission methods



Source. Kim et al. (2018)
Note. Original in Korean, translated into English.

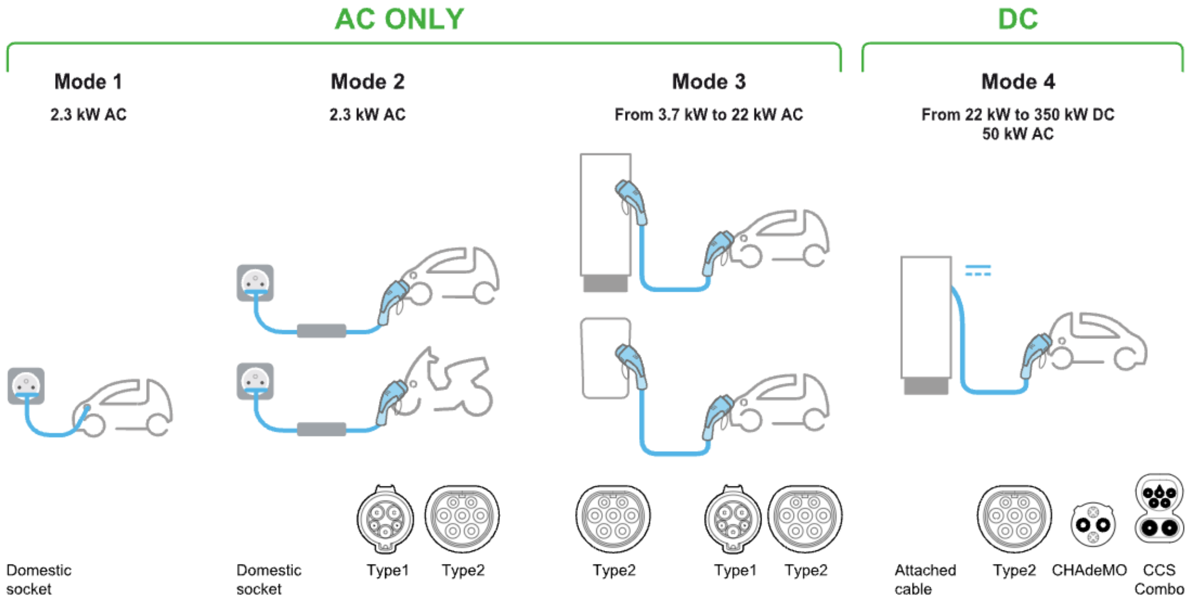
2.5.4 EV Charging Standards and EV Initiatives

The International Electrotechnical Commission (IEC) governs the EV charging standards and ensures that the EVs operate and connect safely to the electric grid (IEC, 2021). One of the main standards for EV charging is IEC 62196, which defines the types of plugs and charging modes (Bahrami, 2020). Schneider Electric (2021) explains the four charging modes and their respective charging plugs (Figure 13). Mode 1 is charging an EV through the standard socket-outlet of the AC network. Due to the limited output power, the charging time takes several hours in charging mode 1.

In addition, mode 1 is the simplest charging method, but because there is no controlling equipment to support this charging mode, it is limited or even forbidden (such as in the United States) to use this mode. Mode 2 uses a control pilot unit with mode 1. While mode 2 comes with a controlling unit, it is limited to domestic electric installation because the charging may require more than 32A, which is the maximum current level defined by the IEC. Mode 3 is when charging is conducted using specific equipment that uses the AC supply network and protection and control functions. This mode is recommended for EV owners because it guarantees safety, and the control function provides optimal battery charging. Finally, mode four is charged through a DC EV charging supply equipment. This mode provides the fastest charging time.

Figure 13

4 Charging Modes defined by IEC 61851



Source. Schneider Electric (2021)

EV's two strongest proponents, Japan's CHAdeMO and China Electricity Council (CEC), are collaborating to develop an ultrafast charging protocol and asking other countries to join to create an open charging standard (Boyd, 2018). CHAdeMO is a consortium of automotive manufacturers, power generation, and IT companies such as KIA and Nissan and has the largest installed DC chargers globally[19] (Boyd, 2018). Similarly, CEC installed more than 270,000 chargers in China and India (Boyd, 2018). In addition, the two proponents and the Japanese and Chinese governments created a charging standard called the ChaoJi, which sets the maximum power to 900 kW so that large vehicles (buses, trucks and helicopters) can also be charged at a fast speed (Boyd, 2018).

South Korea also announced its plan to promote domestic EV wireless charging technology as an international standard (Yonhap, 2021). Korea proposed an EV wireless charging of 50kW capacity, up to 80% of the battery within 60 minutes, as a global standard to the IEC in 2020 (Yonhap, 2021). However, on October 22, 2020, the Society for Automotive Engineers (SAE) International announced the first global standards for wireless charging for EVs (Shuttleworth, 2021). SAE J2954 will play a key role in accelerating the adoption of EVs and autonomous vehicles.

The United States has three major charging standards (Hove and Sandalow, 2019). The first is CHAdeMo. In 2011, the CHAdeMO standard was introduced in the United States with a charging rate of 70 kW but was upgraded to 400 kW in 2018 Hove and Sandalow, 2019. The second standard is CCS or SAE Combo, released in 2011 by US and European manufacturers (Hove and Sandalow, 2019). This standard allows CCS plugs to enable DC and AC charging. The third standard is the Tesla Supercharger network in the United States. Tesla offers charging at the maximum level of 120 kW and operates 595 supercharger stations in the United States (Hove and Sandalow, 2019). In addition, Tesla announced that they would offer as high as 350 kW charging in their supercharger stations in the future. Recently, as part of the newly signed

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[19] More than 22,647 charging stations in 71 countries (Boyd, 2018)

1.2 trillion-dollar infrastructure bill, the Biden administration is investing 7.5 billion dollars for EV charging and related programs and hopes to create 500,000 public charging stations by 2030 (Keane, 2021). The Michigan Department of Transportation announced a pilot initiative to develop United States' first wireless charging infrastructure on a public road (Frezell, 2022)

There is also a multi-government policy forum called the Electric Vehicles Initiative (EVI), which was established in 2010 under Clean Energy Ministerial (CEM) and coordinated by the IEA, to deploy electric vehicles worldwide by assisting governments in understanding policy challenges related to electric mobilities (IEA, 2021). In addition, the EVI raises awareness of EVs and electric mobilities through different CEM campaigns such as EV30@30 and the Drive to Zero Campaign.

2.5.5 EV Industry and Wireless Charging Technology in Korea

The South Korean government's Green Car Initiative and growing interest in environmental issues, such as air pollution due to fine dust, are a major public concern, stimulating the growth of the EV market in South Korea (Yoon, 2022). In 2019, more than 600 thousand clean energy vehicles (EVs and hybrids) were registered. In the early stages of EVs, the government had restrictions on subsidies for purchasing EVs. Initially, the battery capacity was the sole factor in providing a subsidy, but now standards for subsidies have significantly improved (Yoon, 2022). South Korea plans to increase clean energy vehicles, such as electric vehicles and hydrogen vehicles and has extended subsidies for purchasing clean energy vehicles (Kim & Kim, 2020).

Korea's largest electric utility, Korea Electric Power Corporation (KEPCO), invented an EV charging platform in 2019 and planned to promote technology transfer activity to domestic and international firms. Further, KEPCO planned to apply its charging platform and connect it to the grid to create a Vehicle-to-Grid (V2G) platform (KEPCO, 2019).

Since 2009, the Korea Advanced Institute of Science and Technology (KAIST) has developed and attempted to commercialize an online electric bus system that can wirelessly charge an electric bus using a power supply coil buried in the road and a current collecting coil built into the bus (Kim et al., 2018). This system was implemented on the roads of Gumi in 2014 and was the first in the world to provide such a service (Kim et al., 2018). Although it is currently partially operating, this system is evaluated as having favorable commercial conditions compared to existing electric vehicles because it can be charged in real-time while running, and the size of the battery can be reduced (Kim et al., 2018). Furthermore, Korea Electrotechnology Research Institute (KERI) created a wireless charging system prototype that charged up to 1m apart with a 900 kHz resonant frequency by using a transmitting resonator and a repeater (Kim et al., 2018).

In January 2021, Hyundai, an automotive manufacturer in South Korea, and SK Networks, a company in the communication industry, collaborated to convert a gas station into an EV charging station (Hyundai, 2021a). According to Hyundai (2021a), the “Hyundai EV Station Gangdong” has the largest and fastest charging capacity in Korea and can charge an EV from 10% to 80% of the battery in just eighteen minutes. In addition, Hyundai announced its plan to develop a remote charging station; however, wireless charging for EVs has been banned previously due to the lack of policies and regulations to allow developers to use certain frequency bands for charging purposes (Kang, 2021). Therefore, the Korean government decided to approve Hyundai to install wireless charging technology to its EVs to help expand Korea's EV industry and improve customer convenience (Kang, 2021).

Despite the efforts and promotion of EVs in South Korea, there are about 23,000 chargers (Lee, 2020), of which only 9,805 are rapid chargers (Park, 2021a). South Korea has just 0.8% of China's charging stations, 1.4% of the US, and 10.1% of Japan (Lee, 2020). Thus, companies like POSCO ICT and KT Corporation install EV charging stations at hotels and convert old telephone booths into charging stations (Edelstein, 2015). Furthermore, Hyundai plans to install 72 ultra-rapid charging stations at motorway rest stops and 48 more across eight cities in South Korea (Manthey, 2021).

2.5.5.2 Cultural Differences in the Use of EVs and EV Charging

It may seem logical to construct EV charging stations similar to gas stations for the public. However, deciding where to construct a charging station may be more difficult. Wu and Niu (2017) examined and highlighted twelve influence factors of EV charging station location. The first three factors (the area attribute or characteristics, the purchase intention of the residents, and the sales of EVs) all relate to the charging demand. The next two factors relate to the construction, annual operating, and charging stations' maintenance fees. The next set o factors are related to the traffic of the charging station location. Specifically, the number of lanes in which the charging station is located, the traffic flow near the charging station, the pit stop rate, a ratio of the number of EVs entering the charging station to the number of EVs passing through the charging station should be considered. The next two factors (impacts on the transmission and distribution network and harmonic pollution to the grid) are related to the power grid security. EVs need to rely on fast charging, and the fast charging mode requires high current output; therefore, charging stations need to be connected to the regional power grid. Finally, the last two factors relate to the social and geographical environment of the charging station location because the operation of the chargers is greatly influenced by temperature, humidity, and other environmental factors.

Smart and Salisbury (2015) constructed multiple AC level 2 and DC fast-charging stations in various locations, such as homes, workplaces, stores, restaurants, gas stations and other venues, throughout the United States to examine where EV owners would charge their vehicles. EV owners tend to charge at their homes and workplaces instead of using the public charging infrastructure. Another interesting point was that the DC fast-charging stations were widely used for in-town and inter-city driving, but only a few AC level 2 charging stations were used. Thus, Smart and Salisbury concluded that charging infrastructure should focus on homes, workplaces and public “hot spots.” Similarly, the US Department of Energy announced that most EV owners expect to charge their vehicle up to 80~90% overnight at their homes or during the day at work (Telang et al., 2021). Furthermore, according to Dr. Kempton, a researcher of EV adoptions at the University of Delaware, 90 to 95% of charging is done at home in the United States (Kaufman, 2020).

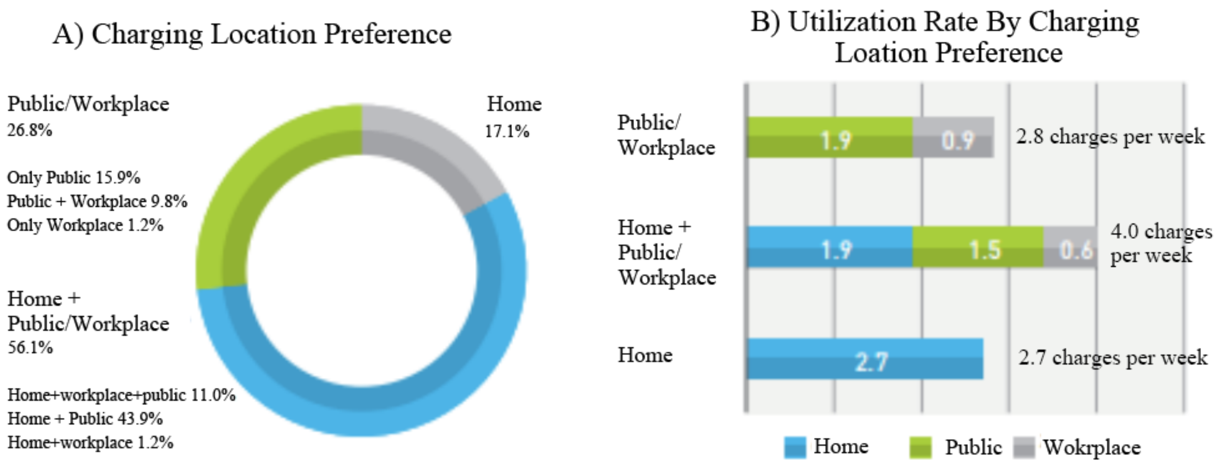
Virta (2021b) gathered utilization rates of 12,000 charging stations in their network from 5 European countries (Denmark, Finland, Norway, Sweden and Switzerland). There are several interesting points. First, one of the most popular charging locations in Finland was the airport, where the utilization rates of chargers ranged from 50% to 95%. Another popular spot in Finland was AC charging stations in residential buildings. Second, similar to the United States, parking lots located in busy areas and traffic knots were frequently used in the five countries. Third, Denmark EV users tend to charge using the DC public fast-charging stations over their AC charging stations, located at residential buildings and workplaces.

While EV owners in the United States rely on home charging, that is not an option for most EV owners in South Korea because more than 70% of the population live in multi-unit dwellings (Park, 2019). In addition, the majority of the charging stations are located in underground parking lots of large buildings in the downtown area and apartments, and each location has only two or three chargers (Park, 2021b). The Korea Transport Institute (KOTI) (2020) researched EV owners' charging habits and found several interesting results. First, 76.8% of chargers located at workplaces were not used. Second, only 17.1% of the EV owners used just the chargers at their homes, compared to 56.1% of the drivers who charged at their homes, workplaces and public locations. Table 7 reviews the difference in EV usage and charging locations in South Korea, the United States and Europe.

Figure 14a, most EV owners charge their vehicles at home and in public locations, and only 1.2% of the EV owners charge only at their workplace. The third is the low usage of chargers. Fourth, EV owners in Korea charge their vehicles at least 2.7 times per week (Figure 1b). Table 7 reviews the difference in EV usage and charging locations in South Korea, the United States and Europe.

Figure 14

Charging location preference and utilization rate by charging location preference



Source. KOTI (2020).

Note. Original in Korean, translated into English.

Table 7
Differences in EV Usage and Charging Locations by Countries

South Korea	United States	Europe
Charging from home is not an option for Koreans as more than 70% of the population live in multi-unit dwellings (Park, 2019)	EV owners tend to charge at their homes and workplaces instead of using the public charging infrastructure (Smart and Salisbury, 2015)	(Finland) One of the most popular charging locations was the airport, where the utilization rates of chargers ranged from 50% to 95% (Virta, 2021b)
17.1% of EV owners only charge at home, while 56.1% of EV owners charges at multiple locations (home, workplace and public locations) (Korea Transport Institute (KOTI), 2020)	DC fast-charging stations were widely used for in-town and inter-city driving (Kaufman, 2020)	(Denmark) EV users tend to charge using the DC public fast-charging stations over their AC charging stations, located at residential buildings and workplaces (Virta, 2021b) (Finland) A popular spot was AC charging stations in residential buildings (Virta, 2021b)
76.8% of chargers located at workplaces were not used (KOTI, 2020)	90 to 95% of charging is done at home (Kaufman, 2020)	Parking lots located in busy areas and crossroads were frequently used in Scandinavian countries and the Netherlands (Virta, 2021b)

2.6 Patent Databases and Their Characteristics

Singh et al. (2016) defined patent databases as a repository of data related to issued patents and published applications. The database includes patent information such as patent numbers, claims, references and more. The USPTO first launched an open database for patents in 1995 and contained more than 326,000 patents in 2014. Today, the USPTO, EPO and JPO are the three major patent offices as they together account for more than 90 percent of patent applications (Singh et al., 2016). In addition, the EPO database, ESPACENET, provides more comprehensive tools and features to conduct a better patent search and is the largest public database.

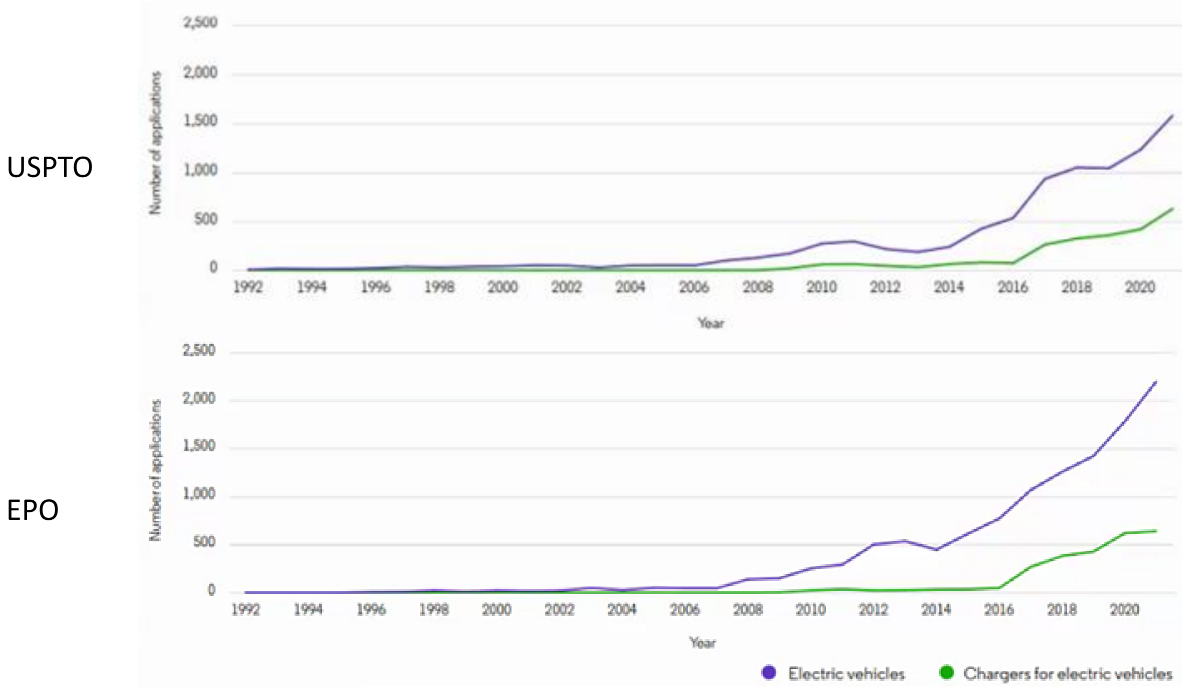
Kim and Lee (2015) investigated the characteristics of patent databases commonly used for innovation trend studies. The authors examined patents filed in the USPTO, EPO, KIPO, and JPO (Japanese Patent Office) between 2008 and 2010 and also the number of annual patents registered in A61 and G06 patent classes over 20 years (1992 to 2011) in terms of "innovation activities," "innovation participants" and "innovation targets." The results show that 1) patent applications in the USPTO and EPO databases were widely used in global innovation studies, 2) the USPTO database provides the most abundant information on technological innovation among the four databases, 3) the USPTO database has the most number of international patent classification (IPC) registered (258), followed by KIPO (122) and EPO (121), 4) EPO database contains the least information, but still provides relatively important information for studying global trends, and 5) USPTO, EPO, and JPO databases satisfy the conditions to be used in innovative studies because unlike the USPTO, EPO and JPO databases, there are fewer international assignees and a higher proportion of patent granted to domestic assignees in KIPO database.

2.6.1 EV Patents

Clarivate (2021) analyzed the EV and EV charger patent applications in the USPTO and the European Union Intellectual Property (EUIPO) between 1992 and 2020, as shown in Figure 15. The number of EV and EV charger patent applications was fairly low until 2006, which was the year Tesla Motors announced its "motor master plan" (Thompson and Lee, 2020) and started producing luxury electric sports cars (DOE, 2014). One interesting point to note is that the difference between the EV and EV charger patent applications grows larger. However, this result may not be as surprising despite the importance of charging for EVs. Globally, there is an overall lack of usable charging infrastructure, and the early development focus has been on

EVs' cost, safety, and energy efficiency (Clarivate, 2021). Furthermore, according to Clarivate (2021), the emerging focus is thermal management, size and shape, range and weight of the EV.

Figure 15
EV and EV charger patent applications in the USPTO and EUIPO between 1992 and 2020



Source. Clarivate (2021)

In the EPO, there has been a steep rise in the patent application relating to EVs, as about 18,000 EV patents have been applied between 2011 and 2017 (Ménière et al., 2018). According to the 2017 data, perception, analysis & decision technology were the top EV technology fields, while communication and computing technologies showed fast growth (Ménière et al., 2018). The patent assignees operated in various industries, such as automotive and technology. While European nations and the United States led the number of patents in 2017 in the EV field, Japan and Korea were the next highest patenting countries.

Borgstedt et al. (2017) examined and conducted a patent analysis on more than 90,000 EV patents from 1990 to 2013. The authors found three key outcomes. First, the innovation pressure shifted from car manufacturers to supply networks due to the uncertainty of the EV industry. Second, powertrain suppliers suffer from technological change. Third, new market entrants benefit from the technological change in the battery EV industry if battery EVs become the new dominance.

Morton et al. (2014) stated that while the UK and EU governments have played a vital role in developing and introducing EVs, there are still uncertainties regarding the viability of EV technologies. Therefore, several studies have examined EVs through patent analysis. For example, (Zhang et al., 2017) analyzed the R&D trends of battery technologies for EVs. In addition, (Pilkington et al., 2002) found an increase in the patenting activities in the EV industries and found that patents included within the International Patent Classification (IPC) were related to many other applications, not only to EVs. Furthermore, Kim et al. (2019) examined the emerging technologies in the wireless power transfer sector in the EV industry by conducting topic modeling and time series analysis.

The EV industry is still growing, but all major automobile companies have already invested in building their patent portfolio (Purificato, 2014). General Motors, Honda, Hyundai, Tesla, Ford, and more have invested their R&D in creating patents in the EV industry. While open innovation and patent sharing have been used as a defensive method in the automobile industry, Telsa Motors decided to share its patents with its competitors to promote EVs and create a better ecosystem (Purificato, 2014). Similarly, Toyota (Toyota Newsroom, 2015) and Ford (Ford Media Center, 2015) has decided to open their patents through licensing. These open-source patents are designed to create a cooperative environment for firms to influence the

EV industry by increasing public policy's emphasis, fostering the standardization process such as charging stations and advancing the technologies (Bloomberg Law, 2019).

2.7 Research Gap

From the literature review, three gaps can be identified.

First, the prior research in technology transfer and commercialization used process-oriented variables such as the number of technology transfer cases and the technology transfer rate in assessing the technology transfer status in countries. While process-oriented variables are important, they do not qualitatively assess the technology transfer and commercialization. Therefore, a performance-oriented variable should also be considered when understanding the technology transfer and commercialization situation.

Second, South Korea has focused on increasing technology transfer and cultivating a technology transfer ecosystem through government-funded projects and programs. However, despite the efforts, technology transfer activities have not led to increased commercialization activities. The low commercialization activity may be that firms cannot catch up with the changing market trends (Kang, 2012). Kang surveyed Korean SMEs in the component and material industry that participated in commercialization activities and found that firms failed to commercialize due to 1) the speed of technological development change, 2) unsuccessful commercialization due to fast trend changes, and 3) patent problems. Kang wrote that the firms developed their technology and product without monitoring the changes in the market trends. In addition, competitors in domestic and overseas markets have already preoccupied the market, causing Korean firms to either fail their commercialization or cease their technology development. Similarly, patent problems were either caused by competitors filing similar technology ahead, causing the SME's technology to lose its value or the change in the market demand due to the rise of more advanced technology.

Third, little has been written about the EV patents or technology transferred or potentially transferred to date. Furthermore, other than Kim et al. (2019), charging technology and the electric vehicle industry have not been widely studied. Few studies examined the patents regarding the technology readiness level or technology innovativeness. However, no studies in technology transfer and commercialization have attempted to examine patents' value, rarity, and inimitability as a success factor. In addition, the competitive advantages of the patents in technology transfer and commercialization have not been examined.

Chapter 3 Proposed Theoretical Framework, Research Questions and Hypotheses

3.1 Introduction

This chapter addresses the framework for the dissertation. The major contribution of this chapter is to generate research questions and hypotheses from the identified research gaps from the previous chapter and provide the research framework that is used to support the research methodology and approach. First, the chapter looks into the different competitive advantage theories and examines why the Resource-Based View (RBV) theory presented by Barney (1991) is perfect for this research. Then, using the framework, the dissertation lays out the performance-oriented variables used to assess technology transfer and commercialization. Finally, the chapter presents the research questions, hypotheses, and an overview of the dissertation.

3.2 Research Framework

3.2.1 Traditional Resource-Based View

Barney's RBV theory has been influential in understanding the firm's strategic management (Barney et al., 2001). Barney (1991) proposed that valuable, rare, imperfectly imitable, and not substitutable firm resources generate a sustained competitive advantage and that some resources are better and more efficient than others. Barney classified the firm's resources into physical capital, human capital, and organizational capital. Physical capital resources were physical technology used in the firm, the firm's plant and equipment, the firm's geographical location, and the access to raw materials. Human capital resources were training, experience, judgment, intelligence, relationships, and individual managers' and workers' insights. Organizational capital resources were formal reporting, planning, controlling, coordinating systems, and the firm's internal and external relationships.

In this theory, Barney (1991) has two assumptions for the RBV: resources must be heterogeneous and immobile. If a firm is first to implement a strategy to obtain a sustained competitive advantage over others, they have a "first-mover advantage" (Barney, 1991; Lieberman & Montgomery, 1988). Barney stated that for a firm to have a first-mover advantage, the firm must have heterogeneous resources. Furthermore, if a firm had homogeneous resources, it would not implement a strategy different from its competitors to outperform them (Barney, 1991). Barney's second assumption is that firms' resources must be immobile since there are barriers to entering an industry. Barney stated that implementing such resources could also be easily acquired if resources were to be mobile.

To sustain competitive advantage, the firm resources must also have VRIN attributes (Barney, 1991; Eisenhardt & Martin, 2000). First, resources must be valuable. Valuable resources enable a firm to implement strategies that improve its efficiency and effectiveness and enable a firm to exploit opportunities and neutralize threats. Second, resources must be rare. If numerous firms possess a valuable resource, that resource cannot be a source of sustained competitive advantage. However, this does not necessarily mean that common but valuable resources are not important. Third, resources must be inimitable. Valuable and rare resources are a source of sustained competitive advantage if competitors cannot obtain them easily. In his other study, Barney (1986a) introduced the idea of imperfectly imitable to describe a firm's culture as a source of sustained competitive advantage. Barney (1991) stated that imperfectly imitable resources are dependent on unique historical conditions, are casually ambiguous, and are socially complex. For example, a resource can depend on the firm's unique historical position or created over a long period.

Similarly, if a resource of a sustained competitive advantage firm cannot be understood, it may be difficult for competitors to imitate the resource. In addition, if a resource can be based on deep and complex social phenomena, it also limits competitors from imitating. Fourth, resources must be non-substitutable. Finally, a non-substitutable resource must not have a strategically equivalent valuable resource.

Barney (1995) examined his framework and introduced a new attribute, organizational, to define sustained competitive advantage firm resources in his later work. A resource must be valuable, rare, and inimitable to be considered a sustained competitive advantage, but a firm must also be fully organized to exploit the resources. For example, reporting structure, management control systems, and compensation policies are complementary resources that a firm organization must have to fully realize the potential of valuable, rare, and inimitable resources (Barney, 1995). Therefore, the dissertation examines the VRIN attributes of EV wireless charging patents and visualizes them in a patent map.

3.2.1.1 Extended Resource-Based View

Teece et al. (1982) highlighted an industry entry decision approach in an RBV-focused firm. The firm should first identify its unique resource, decide on the market where the resource can maximize return, and then decide whether to integrate it into integrated markets, sell the resource to other firms, or sell to other firms. In his other work, Teece et al. (1997) stated that RBV does not address the resources and firms' competitive advantages in a rapid and unpredictable environment. While high-tech firms like IBM and Phillips followed the RBV strategies, the RBV strategy is not enough to support competitive advantage since highly competitive firms demonstrated rapid responses, flexible product innovation, and high management capabilities (Teece et al., 1997). Teece et al. highlighted that a firm's ability to integrate and reconfigure internal and external competencies or dynamic capabilities is important in a fast-changing environment. The authors also stated that a firm's competitive advantage lies in the processes, assets, positions, path, and opportunities, and if the capabilities and assets are difficult to imitate.

Furthermore, Eisenhardt and Martin (2000) defined dynamic capabilities as integrating, gaining, and releasing resources to match and create market changes. Furthermore, the authors suggested that dynamic capabilities are exhibited in moderately dynamic markets, according to the traditional RBV theory and its properties. However, firms' dynamic capabilities cannot be a source of competitive advantage in a high-velocity dynamic market unless those capabilities were used "sooner, more astutely, or more fortuitously" than competing firms. Therefore, dynamic capabilities are embedded in existing knowledge in a moderately dynamic market, but new knowledge must be gained rapidly and consistently (Eisenhardt & Martin, 2000).

In his later work, Barney et al. (2001) agreed with Eisenhardt and Martin regarding the need for the dynamic capabilities to be used "sooner, more astutely, and more fortuitously." Nimbleness, the ability to change quickly in the market, is costly for competitors to imitate, and thus it is a source of sustained competitive advantage (Barney et al., 2001). The authors concluded that Eisenhardt and Martin's statement of a firm being "more fortuitous" in applying its dynamic capabilities aligns with Barney's (1986b) concept of luck and the future potential of resources. Whenever there is a positive difference between the actual returns and the resource's expected returns, the result displays the firm's unexpected good fortune (J. B. Barney, 1986b).

Furthermore, Barney (1986b) suggested that a strategy factor market is developed whenever a firm purchases or sells a resource to implement its strategy. According to Lee and Barney (2016), a strategic factor market is when firms acquire or sell resources necessary for implementing their product strategy. The price for acquiring a resource in the strategic factor market is important in creating a competitive advantage (Barney, 1986b). This price is determined by the firm's view of the resource's potential value. The more firms value the resource's potential, the resource's price is around the competitive price. However, if only a few firms value the resource, the price is below the competitive price. Therefore, Lee and Barney (2016) highlighted that the strategic factor market should be considered the essential foundation of the RBV theory.

3.2.2 Other Competitive Advantage Theories

A firm obtains a competitive advantage when developing or obtaining a set of actions or attributes to outperform its competitors (Wang, 2014). Wang (2014) highlighted two dominant theories regarding competitive advantage: the Market-Based View (MBV) and RBV. The MBV emphasizes that the industry factors and external market orientation as the top two primary determinants of firm performance (Bain, 1968; Wang, 2014). On the other hand, RBV emphasizes the importance of firms' internal environment as the key driver for firms' competitive advantage (Barney, 1991; Wang, 2014).

Furthermore, as shown in Table 8, Hamilton (2015, 2018) and Hamilton & Philbin (2020) summarized the different competitive advantage theories for technology transfer. The knowledge-Based View considers knowledge as the most strategically significant resource of a firm, but Wang (2014) states that KBV was derived from the RBV. The theory of environmental munificence is the lack of or abundance of critical resources for a firm to operate in an environment, and some environmental elements are more important to particular organizations (Castrogiovanni, 1991). The resource dependency theory (RDT) examines how external resources such as raw materials affect a firm's behavior (Pferrer and Salanick, 1978). Finally, the attention-based view (ABV) centers around the decision makers' focus of attention and its impact on strategic choices and outcomes (Ocasio, 1997).

Table 8
Different Competitive Advantage Theories for Technology Transfer

Theorists	Competitive Advantage Theories That Best Explain Tech Transfer
Barrney (1991)	RBV
Grant (1996)	Knoweldge-Based View (KBV)
Castrogiovanni (1991, 2002)	Theory of Environmental Munificence
Pferrer and Salanick (1978)	Resource Dependency Theory (RDT)
Cyert and March (1963) **Ocacio (1997)**	Attention-Based View (ABV)
Ocasio (1997)	Combination of RBV and RDT

Source. Hamilton (2015, 2018), Hamilton & Philbin (2020)

While the different theories of competitive advantage explain the various perspectives of technology transfer and commercialization, this dissertation uses the RBV as the theoretical framework. Barney et al. (2001) highlighted that the RBV theory could be applied to technology transfer from the university to a spinoff. The RBV focuses especially on the inside of the firm and its resources (Curado, 2006). Hamilton (2015) explained that there are no common theoretical foundations in technology transfer studies, but RBV theory can be applied to highlight the importance of resources with organizations' sustained competitive advantage. Moreover, the RBV best describes the transfer of patented technology into the commercial marketplace within the realm of low technology transfer licensing revenue in South Korea than the United States. Patents can also be understood as resources that include investments in R&D, tech commercialization, researchers' quality and more.

3.2.3 Patent as Resources

Markman et al. (2004) highlighted that patents are *firm-specific capabilities to capture some of the intermediate outcomes of the innovation process*. The authors looked at pharmaceutical patents and claimed the patents could be seen as a competitive resource. Similarly, Chondrakis (2012) stated that patents are strategic resources that help firms sustain their competitive advantage because patents follow RBV's four attributes: valuable, rare, inimitable, and non-substitutable. Furthermore, patents are an important source of resources because they discourage imitations (Chondrakis, 2012). Finally, Penrose (1959) stated that patents could help firms with revolutionary innovation ward off competition and keep developing their advantage.

Patents are examples of a firm's resources and give its owners a competitive advantage through exclusive rights to use and sell for years. In addition, whether patented technology is not easy to imitate or substitute depends on how the patent claims are drafted. In addition, patents are either licensed (rented) or assigned (sold). So it is desired for patents to be transferred. When transferred, the patent owner earns revenues. So, in a way, the transfer of technology is evidence of the firm gaining a competitive advantage.

3.2.3.1 Patent and Value

Patents can create and preserve technological advantage by granting a temporary monopoly (Harrigan et al., 2017) while excluding competitors from the market (Bessen, 2008).

According to Markman et al. (2004), patents are, by definition, valuable. Past research has measured patent value, from inventive outputs to patents' incentive effect (Bessen, 2008). The dissertation uses the number of forward citations to measure the value of patents.

Forward citations refer to the number of cited subsequent patents and have shown a positive correlation with the value of the patent (Falk & Train, 2017). Forward citations have been widely used to measure knowledge diffusion (Alcacer & Gittelman, 2006). Furthermore, forward citations are a good indicator of potential market as the larger number of forward citations reveals the existence of research efforts, suggesting that further technology development is taking place (Van Zeebroeck, 2011). The OECD (2015) stated that the number of forward citations mirrors the patent's technological importance and the invention's economic value. There is typically an eighteen-month delay for a patent to be publicized, and forward citations are counted for five or seven years after publication. Furthermore, Allison and Mann (2007) stated that the number of forward citations is an "intuitively and empirically" validated indicator that shows positive correlations to the market value. Therefore, the dissertation assumes that a higher number of forward citations increases the value of a patent.

3.2.3.2 Patent and Rarity

Patents are rare by definition (Markman et al., 2004) and because novelty and non-obviousness are patentability requirements to file a patent (Reitzig, 2005). The patent includes structural data, such as the number of forward citations and claims, and non-structural data, such as the abstract and other text data (Kim and Lee, 2017). The text data have been major targets in the patent analysis because many studies perceive meaningful value by assessing them (Kim and Lee, 2017).

Latecki et al. (2007) defined outliers and anomalies as rare events. Furthermore, by definition, outliers are rare data points far from regular data (Kotu & Deshpande, 2019). Aggarwal (2017) stated that noises might not provide useful information, but anomalies may provide meaningful information. Furthermore, the authors highlighted that one way to distinguish noises and anomalies is that anomalies have a much higher "outlier" score than noises. Data science uses outliers and anomalies interchangeably (Lyashenko, 2022). Therefore, the dissertation assumes that a higher outlier score increases a patent's rarity.

3.2.3.3 Patent and Inimitability

Patents are inimitable because patents provide monopolistic protection that raises barriers for imitators (Markman et al., 2004). Markman et al. (2004) tested the inimitability through forward citation because the USPTO requires patents to cite the previous patents. Furthermore, if a patent is strong, there is more attraction for the patent to be cited. Similarly, if a patent has many forward citations, it increases the patent owners' protection, causing problems for competitors to imitate (Markman et al., 2004). The authors also found a positive relationship, but only marginally related, between the number of forward citations and the commercial success rate of new products.

Lee et al. (2015) found that patents with higher forward citations showed a more technological and economic impact. Also, for every patent forward citation, the market value of a firm increases by three percent (Hall et al., 2005). Moore (2005) examined patents issued in 1991 and analyzed the differences between expired patents to those still maintained after eight and twelve years. Moore found that patents that were maintained longer had a greater number of forward citations. For example, the average number of forward citations for patents still maintained after twelve years was 7.13, while for patents that expired within four years, it had a forward citation count of 4.03. Furthermore, a high citation rate is associated with distinct innovation (Jaffe et al., 2000). Therefore, the dissertation assumes that a higher number of forward citations increases the inimitability of a patent.

3.2.3.4 Patent and Non-Substitutability

Markman et al. (2004) stated that once a patent protects a technology, substitution becomes extremely difficult, costly, and time-consuming because slightly modified or similar technology would be patented. The authors also highlighted that the notion of non-substitutability has been neglected and failed to find a single empirical study in top journals that operationalized non-substitutability. Therefore, the authors used the number of claims to operationalize non-substitutability because claims describe the patent's distinct inventions. Markman et al. (2004) continued to point out that many claims have a broader scope, thus, more substitutable by lowering the legal barriers for competitors and lowering the ability to defend the patent. Furthermore, it would be extremely difficult to substitute if a patent is very narrow in claims (Markman et al., 2004). Markman et al. (2004) also found that the number of claims is negatively related to new products' commercial success rate. In addition, Lerner (1994) quoted that broader patents "are significantly more likely to have been litigated."

Moore (2005) found that expired patents had fewer claims than patents that expired later. Patents that were still maintained after twelve years had, on average, 13.27 claims, while patents that were only maintained for four years had, on average, 11.44 claims. In addition, the more claims a patent has the broader the property rights protection (Lee et al., 2015; Song & Li, 2014). Therefore, the dissertation assumes that a higher number of claims decreases the non-substitutability of a patent.

3.2.4 Emerging Trends and Competitive Advantage of Firms

With many new technologies introduced quickly, it is important to understand the existing technologies and have a better idea of technological development. Therefore, emerging trends are widely studied. Chen et al. (2017) used topic modeling to identify temporal trend patterns and semantic topics. Choi & Song (2018) used topic modeling to explore technological trends. Rotolo et al. (2015) define "emerging technologies" as technologies with five attributes: i) radical novelty, ii) relatively fast growth, iii) coherence, iv) prominent impact, and v) uncertainty and ambiguity. The dissertation defines emerging trends as state-of-the-art technologies with high popularity and sets a new trend (National Council of Educational Research and Training (NCERT), 2021).

Nevens et a. (1990b) found a positive relationship between a firm's competitiveness and its ability to commercialize. Moreover, Bharadwaj (2000) found that IT capabilities are critical for firms to sustain their competitive advantage. In addition, firms must proactively discover emerging trends that enable business models to have a competitive advantage, maximize value by reducing operational costs and overcome legal hurdles in the digital economy (Walker et al., 2016). Therefore, the dissertation detects emerging trends for EV wireless charging technologies.

3.3 Research Questions and Hypotheses

Based on the gaps identified in the previous chapter and the proposed theoretical framework, the research questions that the dissertation addresses are 1) whether or not and how patents can be used to identify emerging technologies and trends to help firms to stay competitive, and 2) whether or not patents with higher competitive advantages in terms of claims, forward citations and abstracts can show promise for generating licensing revenues.

The dissertation identifies emerging technology with patent abstracts to answer the first question. As stated in the previous chapter, there are three types of EV wireless charging methods (MI, MR, microwave) and potentially a new method, as stated by ETRI. While the current state of wireless charging technology is not mature enough to be widely implemented, patents are generated and published regarding wireless power transmission for EVs. The MI coupling method is the most mature, as it is used widely in other products, such as mobile phones, despite the limited power transmission distance of the three methods (June & Oh, 2019). Given that topic trend analysis using topic modeling can be used to find emerging technologies and patent activities of different EV wireless charging technologies, the dissertation suggests the following hypothesis regarding the wireless charging technology trend.

H1: Since MI is the most mature technology widely used in other products such as mobile phones, more patents will be published on **MI coupling** than **MR coupling** or **microwave (IR, RF) power transmission.**

To answer the second question, the dissertation examines patent abstracts, the number of claims and forward citations for value, rarity, and non-imitable and non-substitutable attributes, thus identifying resources with a sustained competitive advantage. Instead of focusing on all of the EV wireless charging patents, the dissertation examines the VRIN-identified patents since VRIN patents are the technologies that provide competitive advantages to the firms and countries, and not the total number of patents. Furthermore, the dissertation aims to provide a performance-oriented assessment of patents that can be used for technology transfer and commercialization. Given that the South Korean technology transfer licensing revenue is lower than that of the United States (Park and Park, 2017), the dissertation suggests the following hypothesis.

H2: **VRIN** EV wireless charging patents filed in **KIPO** have **lower average** VRIN attributes than **VRIN** EV wireless charging patents filed in **USPTO**.

Also, according to Kim and Lee (2017), South Korea has only half of the technology transfer cases compared to Europe. Therefore, given the literature, the dissertation suggests the following hypothesis.

H3: **VRIN** EV wireless charging patents filed in **KIPO** have **lower average** VRIN attributes than **VRIN** EV wireless charging patents filed in **EPO**.

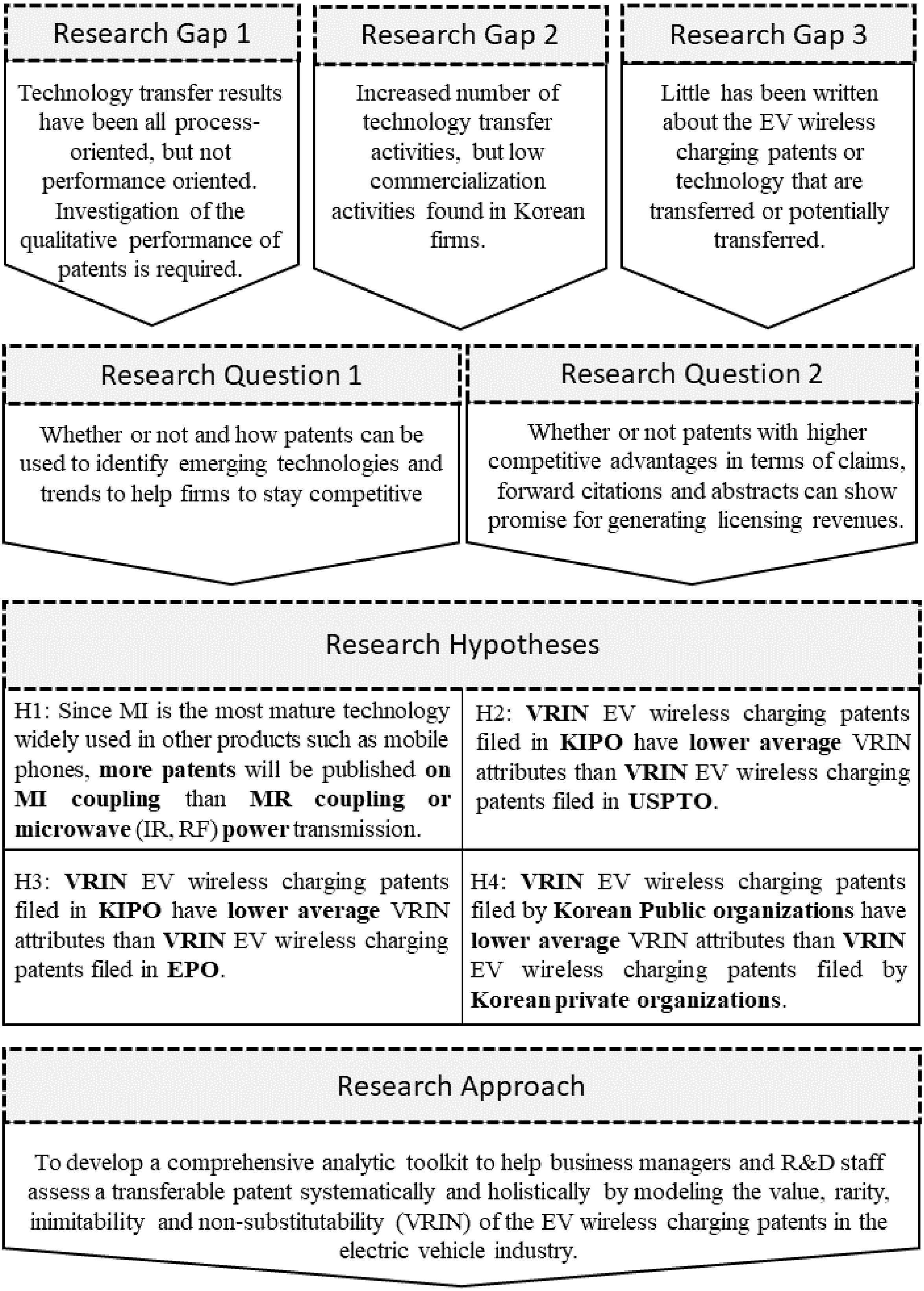
MSIT (2020) reported that the automotive industry is led by private sector R&D, while the robotics industry is led by the public sector R&D. Furthermore, the private sector investment in the automotive industry is 26.29 times more than the public sector investment. Also, as stated in the previous section, 70% of the public technologies are not transferred, and only 15% of the transferred technologies are commercialized. Given the literature, the dissertation suggests the following hypothesis.

H4: **VRIN** EV wireless charging patents filed by **Korean Public organizations** have **lower average** VRIN attributes than **VRIN** EV wireless charging patents filed by **Korean private organizations**.

To answer the research questions and test the hypotheses, the dissertation develops a comprehensive analytic toolkit that may help policymakers, funding agencies, and even R&D managers to forecast the emerging trends in a specific technology and a way to identify patents with a sustained competitive advantage, in terms of VRIN attributes, thus creating a higher likelihood of commercialization success. With the research outcomes, R&D teams can identify patents with the attributes to sustained competitive advantage and achieve higher technology commercialization success. Figure 16 summarizes the overview of the dissertation.

As a case study, the dissertation examines the competitive advantage, in terms of VRIN attributes, of EV wireless charging patents registered in KIPO and compares them to similar patents in the USPTO and EPO. In addition, the dissertation compares EV wireless charging patents owned by Korean public organizations and compares the VRIN attributes to similar patents owned by Korean private organizations. Thus, the dissertation contributes to the technology transfer and commercialization literature by systematically analyzing patents' sustained competitive advantage and identifying emerging technology areas for EV wireless charging. Furthermore, governments, firms, and researchers need to keep up with the change to stay relevant and competitive with technologies evolving rapidly.

Figure 16
Overview of the dissertation



Research Gap 1

Technology transfer results have been all process-oriented, but not performance oriented. Investigation of the qualitative performance of patents is required.

Research Gap 2

Increased number of technology transfer activities, but low commercialization activities found in Korean firms.

Research Gap 3

Little has been written about the EV wireless charging patents or technology that are transferred or potentially transferred.

Research Question 1

Whether or not and how patents can be used to identify emerging technologies and trends to help firms to stay competitive

Research Question 2

Whether or not patents with higher competitive advantages in terms of claims, forward citations and abstracts can show promise for generating licensing revenues.

Research Hypotheses

H1: Since MI is the most mature technology widely used in other products such as mobile phones, **more patents** will be published **on MI coupling** than **MR coupling or microwave** (IR, RF) **power** transmission.

H2: **VRIN** EV wireless charging patents filed in **KIPO** have **lower average** VRIN attributes than **VRIN** EV wireless charging patents filed in **USPTO**.

H3: **VRIN** EV wireless charging patents filed in **KIPO** have **lower average** VRIN attributes than **VRIN** EV wireless charging patents filed in **EPO**.

H4: **VRIN** EV wireless charging patents filed by **Korean Public organizations** have **lower average** VRIN attributes than **VRIN** EV wireless charging patents filed by **Korean private organizations**.

Research Approach

To develop a comprehensive analytic toolkit to help business managers and R&D staff assess a transferable patent systematically and holistically by modeling the value, rarity, inimitability and non-substitutability (VRIN) of the EV wireless charging patents in the electric vehicle industry.

Chapter 4 Research Methodology

4.1 Introduction

This chapter introduces the different research techniques used in the dissertation to answer the research questions and test the hypotheses. Two main techniques are used to find emerging trends and create a patent map for EV wireless charging patents from EPO, KIPO, and the USPTO. First, the topic trend analysis using topic modeling reveals emerging wireless charging technologies in the EV industry by ranking the topics and examining the topic's significance over time. Topic modeling is first conducted on the patent abstracts to identify topics. The dissertation then applies probability coherence and topic prevalence and visualizes topic significance over time. Second, patent mapping is used to visualize the VRIN attributes of patents. The patent map uses the number of patent claims and forward citations as the axes and uses the principal component analysis (PCA) and local outlier factoring (LOF) to identify the rarity of the patents. In addition, the dissertation conducts a model validation process for the patent map through an online questionnaire to patent and technology transfer experts. Table 9 shows how each research technique helps identify patents with a competitive advantage and helps answer the research questions and hypotheses.

Table 9
How Each Research Technique Addresses the Research Questions and Hypotheses

Research Techniques	Other techniques Used with the main technique	Research Outcomes	Connection to the Research Questions and Hypotheses
Topic Trend Analysis using Topic Modeling	Coherence and Prevalence for Topic Ranking	Emerging trends and topic rankings in patent abstracts	Question 1 Hypothesis 1
Patent Mapping	PCA LOF Online Questionnaire	A visualization of patents' performance-oriented variables that helps to compare the competitive advantage levels of patents	Question 2 Hypotheses 2 to 4

The following chapter presents the research method to answer the research questions and test the hypotheses presented in the previous chapter. Section 4.2 explains topic modeling, PCA, LOF, patent mapping and validation process. Finally, Section 4.3 discusses the research approach in detail.

4.2 Research Techniques

4.2.1 Topic Modeling

The dissertation conducts a topic trend analysis using topic modeling to extract the emerging technologies in the EV wireless charging sector. According to Abbas et al. (2014), patent visualization is used with a text mining approach to extract patent documents. Topic modeling is one of the text mining methodologies that extracts topics or themes from an extensive collection of documents known as a corpus. Blei and Lafferty (2007) stated that topic modeling assumes that 1) the word in a document arises from a mixture of topics and 2) that the topic is a distribution over the vocabulary. In addition, the authors noted that topic modeling could extract the interpretable and useful structure of the document.

Topic modeling is an unsupervised learning method, which means it is a model that uses probability distribution to find patterns. By discovering patterns and hidden relationships in texts and documents, topic modeling techniques help identify documents with similar words and topics and annotate documents according to the topics of words discovered (Alghamdi & Alfalqi, 2015). Furthermore, topic modeling provides a convenient way to summarize and understand an extensive collection of text-based information (Blei, 2012).

The basis of topic modeling is Latent Semantic Indexing (LSI), but it is not a probabilistic model (Deerwester et al., 1990; Liu et al., 2016). In 2001, Hoffman (2001) proposed the

Probabilistic Latent Semantic Analysis (PSLA) based on LSI (Liu et al., 2016). Furthermore, in 2003, Blei et al. (2003) proposed a complete probabilistic generative model by extending the concept of PLSA. Moreover, this method, known as the Latent Dirichlet Allocation (LDA), uses a Dirichlet probabilistic model (Blei et al., 2003) and is a well-known topic modeling analysis and a powerful tool that can outperform other dimension-reduction techniques (Blei et al., 2003). According to Liu et al. (2016), other probabilistic topic modeling models have used LDA as the foundation.

Alghamdi and Alfalqi (2015) examined the differences and limitations of four types of topic modeling methods. First, the Latent Semantic Analysis (LSA) creates a vector-based output that computes the similarity between texts. The LSA is an improved version of the LSI and uses Singular Value Decomposition (SVD)[20]. However, the LSA does not have a robust statistical background, making it hard to obtain and determine the number of topics (Alghamdi & Alfalqi, 2015). In addition, the LSA finds the best low-rank approximation of a document-term matrix (Boyd-Graber et al., 2017).

Second, the PLSA model identifies the different contexts of word usage (Alghamdi & Alfalqi, 2015). The PLSA can handle polysemy, or words that can have multiple meanings, and have been used in various fields such as information retrieval, natural language processing, and machine learning from text (Alghamdi & Alfalqi, 2015). According to Alghamdi and Alfalqi (2015), one of the main applications of PLSA is question recommendation tasks. Despite the advantages, PLSA cannot conduct a probabilistic model on the document-level corpus (Alghamdi & Alfalqi, 2015).

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[20] According to Alghamdi and Alfalqi (2015), the SVD is a method that uses a matrix to reconfigure and calculate all the dimensions of vector space

Third, the LDA, a completely unsupervised technique for topic discovery in a large document corpus, is an improved model over the LSA and the PLSA. LDA can deal with a large corpus, and through a discrete distribution, the topics and words are identified to reflect the corpus's properties. The LDA has been used in applications such as social network analysis (Alghamdi & Alfalqi, 2015; McCallum et al., 2007), automatic essay grading (Alghamdi & Alfalqi, 2015; Kakkonen et al., 2006), detecting phishing emails (Alghamdi & Alfalqi, 2015; Bergholz et al., 2008), and detecting emerging trends (Chen et al., 2016; Choi & Song, 2018; Liu et al., 2016). However, the LDA does not automatically remove stop words[21]and cannot visualize the relationship among topics (Alghamdi & Alfalqi, 2015). Fourth, the Correlated topic model (CTM) uses the LDA discovered topics to create a relationship among topics (Alghamdi & Alfalqi, 2015). In addition, the CTM requires much calculation and has a lot of general words inside the topics (Alghamdi & Alfalqi, 2015).

Therefore, the dissertation uses the LDA method over the other three methods because not only is LDA an advanced version of the LSA and the PLSA, but it also has been used to detect emerging trends. Table 10 explains the importance of topic modeling in the dissertation, the data used, and the expected result.

Table 10
Topic Modeling in the dissertation

Why is Topic Modeling Needed in the dissertation	Identify emerging trends by analyzing topic trends and topic rankings
What Data is Used	Patent Abstract (Text) Patent-Keyword Matrix FItldaModel() function from the *"textmineR"* package in R
What are the Expected Results	Emerging Trends in the EV Charging Systems Patents Changes in the topic's significance over the years

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[21] Commonly used word or terms in any language. For example, in English, "he," "she," "they" are examples of stop words

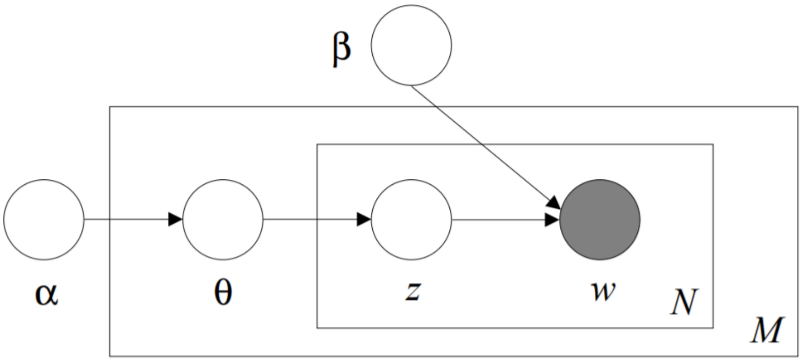
4.2.1.1 Latent Dirichlet Allocation

The LDA's basic idea is that documents in the corpus can be represented as *"random mixtures over latent topics, where each topic is characterized by a distribution over words"* (Blei et al., 2003). Two primary principles guide the LDA model. First, the model assumes that the words of each document arise from a mixture of topics in particular proportions. Second, the model also assumes that each topic is a mixture of words, where the same words can be shared between topics (Blei et al., 2003; Blei & Lafferty, 2007). Therefore, LDA assumes the following generative process for a corpus D with M number of documents, with N number of words in each document w (Blei et al., 2003):

- Choose N ~ Poisson (ξ)
- Choose θ ~ Dir(α)
- For each of the N words w_n: a) choose a topic z_n ~ multinomial(θ) and b) choose a word w_n from P($w_n|z_n$,B), a multinomial probability conditioned on the topic z_n

Blei et al. (2003) modeled the LDA in a three-level Bayesian graphical model. In the model, α refers to the Dirichlet parameter; θ refers to the document-level topic variables; z refers to the pre-word topic assignment; w refers to an observed word, and B refers to the topics. Figure 17 depicts the three-level graphical model of the LDA.

Figure 17
Three-level graphical model of the LDA



Source. Blei et al. (2003)

Furthermore, with parameters α and β, the joint distribution of a topic mixture θ with a set of Topics z and set of words w is computed by Equation 1:

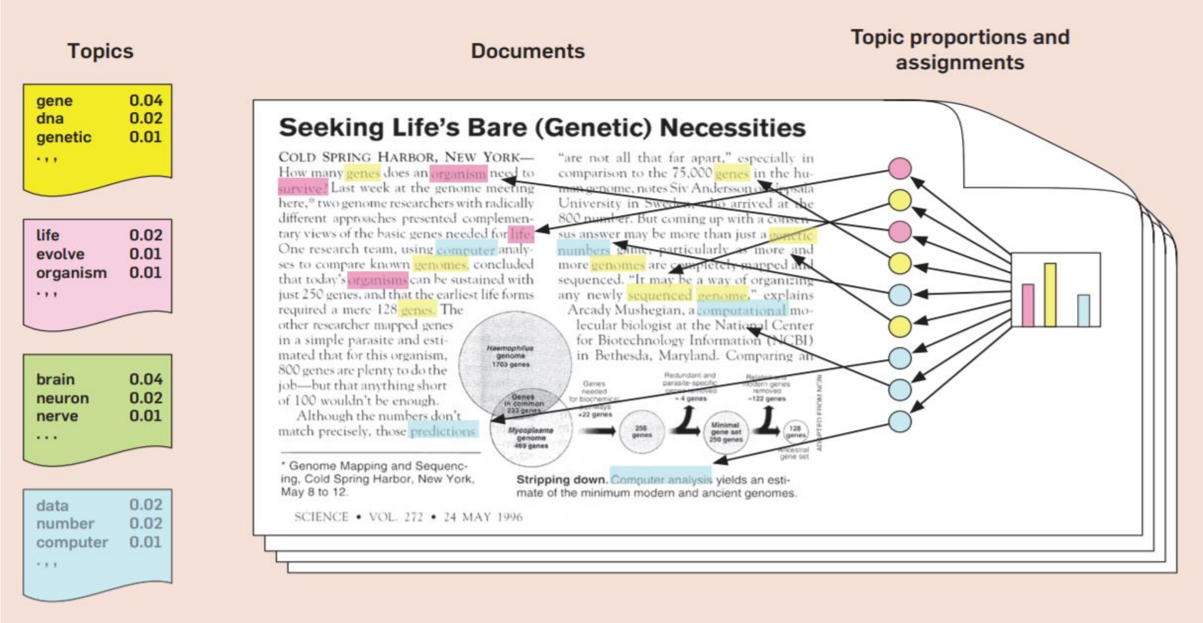
$$p(\theta, z, w|\alpha, B) = p(\theta|\alpha)\prod_{n=1}^{N} p\,(z_n|\theta)p(w_n|z_n, B)$$ Equation 1

Finally, the probability of corpus D can be computed with Equation 2:

$$p(D|\alpha, B) = \prod_{d=1}^{M}\left(\int p\,(\theta_d|\alpha)(\prod_{n=1}^{N_d}\sum_{z_{dn}} p\,(z_{dn}|\theta_d)p(w_{dn}|z_{dn}, B))\;d\theta_d\right)$$ Equation 2

According to Blei (2012), a number of topics exist for the whole collection of documents. First, randomly choose a distribution over topics. Then, each word in the document randomly chooses a topic from the distribution and randomly chooses a word from the corresponding distribution over the vocabulary. Figure 18 explains the topic assigning of the word inside the document sample. In other words, topic modeling automatically discovers topics and the most frequent words for each topic from a collection of documents.

Figure 18
Topic assigning from document sample



Source. Blei (2012)

There are several advantages to conducting LDA topic modeling. First, Boyd-Graber et al. (2017) stated that the LDA is a popular approach in topic modeling, and many researchers have made modifications to the approach. The authors stated that LDA has fewer limitations than the LSA, making it easier to tweak the model. Second, topic modeling can be incorporated with metadata and other data such as author, title, links, and geographical location (Blei, 2012). However, Blei (2012) also highlighted three assumptions while conducting topic modeling: LDA assumes that the order of words (or bag of words) does not matter. LDA also assumes that the order of documents inside the corpus does not matter. Finally, LDA is conducted with a fixed and known number of topics.

Topic modeling is needed to identify emerging technologies by analyzing the change in the topics over the years. Topic modeling has been previously used to examine the trends of emerging technologies. For example, Chen et al. (2017) used topic modeling to identify temporal trend patterns and semantic topics. Choi & Song (2018) used topic modeling to Explore technological trends. Topic modeling uses patent abstracts as input in the format of a patent-keyword matrix. The expected result from the topic modeling is a change in topic trends over the patent years. For example, the most recent topic should be the most emerging technological area in EV wireless charging technology.

4.2.2 Patent Mapping

The dissertation conducts patent mapping to help visualize the VRIN attributes of patents and examine which EV wireless charging patents have competitive advantages. Kim et al. (2008) stated that visualization is the proper way to represent patent information and its analysis results. Yoon et al. (2002) emphasized that patent mapping has been increasingly popular among practitioners and researchers but has limitations due to patent databases' size. The authors also stressed that sophisticated data mining techniques are needed to understand the patent database fully.

Suh and Park (2006) proposed a patent clustering mapping with semantic analysis. The authors stated that a keyword-patent matrix is needed to create a patent map. Similarly, Lee et al. (2015) proposed a patent map that used the number of citations and the number of claims as the axis to visualize the patent information.

The patent mapping is needed to help visualize the patent information in one image and combine the VRIN attributes to a single visualization to compare the patents better. The patent map explains why Korean tech transfer performance is lower than in the USA. This map provides evidence that if Korea increases financial investments in EV VRIN attributes, it can help improve tech transfer performance in the EV case. This methodology can be used in other industry sectors. Table 11 explains the importance of patent mapping in the dissertation, the data used, and the expected result.

Table 11
Patent Mapping in the dissertation

Why is Patent Mapping Needed in the dissertation	To visualize the VRIN attributes of the patents To easily compare the Korean transferable patents to the USPTO patents and Korean Private Company patents
What Data is Used	Outlier Score = LOF Score, but normalized Normalized number of Forward Citations & Claims ggplot() function from the "*ggplot2*" package in R
What are the Expected Results	Explain why Korean tech transfer performance is lower than in the USA. This map provides evidence that if Korea increases financial investments in EV VRIN attributes, this improves tech transfer performance in the EV case. Furthermore, this methodology can be used in other industry sectors.

4.2.2.1 Patent Mapping and Decision Making

According to Mailänder (2013), many companies exploit patent information and utilize patent analytics:

1) identify existing solutions/technologies for technical problems,

2) check for potential infringements of IP rights,

3) monitor competitors,

4) identify business opportunities and development options, and

5) strategic R&D planning

Visualization has been used with patent analytics because it facilitates the comprehension and communication of the analytical results. According to IP Checkups (2017), patent landscape analysis is referred to as patent mapping and is a multi-step process, using both computer and human intelligence to parse, organize, and extract value from a corpus of patents.

A well-constructed patent landscape analysis and its information enable firms, research institutes, and investors to understand new technologies, see product development opportunities, and help make better decision-making before making investments (IP CheckUps, 2017). Moreover, Trippe (2018) stated that patent landscape reports[22] support informed decision-making by addressing concerns in technologically advanced areas. As a result, governments, businesses, and academia rely on broad patent mapping to examine the innovation landscape (Trippe, 2015).

Therefore, the dissertation examined the number of studies related to patent mapping. A Stonybrook Library search for English journal articles with the terms “patent mapping” or “patent map” between 2000 and 2021 resulted in 1,671 results. Figure 19 shows the number of articles related to patent mapping published between 2000 and 2021. There are several interesting points to note. First, it does not consistently increase in articles published each year. The lowest number of articles published was in 2001 with 24 articles, and the highest was in 2017 with 136 articles. Second, after an increase from 2005 to 208, there was a slight decrease in 2009 and another drop in 2011. Third, after an increase in 2017, which might have been due to the USPTO announcing a special issue on IP for the International Journal of the Economics of Business (IJEB), the number of articles published on patent mapping dropped in 2018, and there has not been a year where more than 106 articles were published per year. Fourth, the trend increases as more articles are published in 2021 than in 2020.

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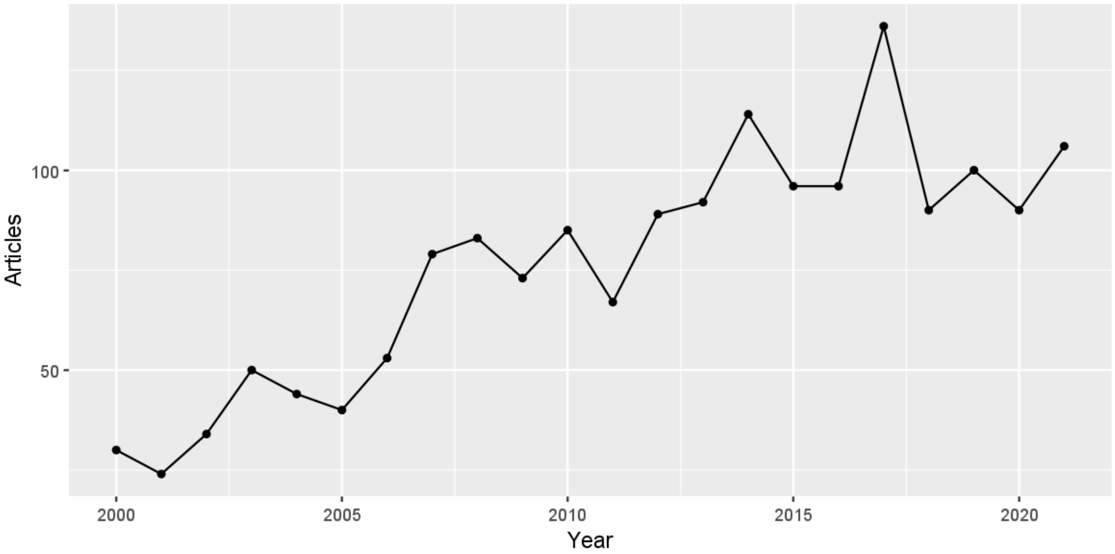
[22] A report that provides a snapshot of the patent situation of a specific technology within a country or region (WIPO, 2021b)

Figure 19
Number of Journal Articles Published Related to Patent Mapping, 2000-2021



4.2.3 Local Outlier Factoring (LOF) and Principal Component Analysis (PCA)

The dissertation conducts a local outlier factoring to examine the value and the rarity of the patents. There are several ways to conduct anomaly detection, known as outlier detection. According to Cheng et al. (2019), isolation forest (iForest) and local outlier factoring (LOF) are widely used in dealing with outlier detection. iForest is sensitive to global outliers and weak in dealing with local outliers. On the other hand, LOF performs well with local outliers but is time-consuming (Cheng et al., 2019). Furthermore, LOF is a novelty detection technique that can identify local outliers for randomly distributed data and does not have incoherent patterns because LOF can treat heterogeneity in its analysis (Lee, 2017).

Furthermore, LOF is used to recognize features different from the rest and, thus, has been used to identify new trends and emerging issues in innovation studies (Yoon and Kim, 2012; Kim & Lee, 2017). Kim and Lee (2017) stated that LOF outperforms clustering methods that only depend on global distance distribution. The LOF can calculate the degree of extremity and better compare outliers in the dataset (Schubert et al., 2014). LOF also uses k-nearest neighbors (kNN) and density models (Kim & Lee, 2017; Schubert et al., 2014).

Breunig et al. (2000) proposed an outlier detection model that introduces the local outlier for each object in the dataset and indicates the degree of outlier-ness. LOF can calculate the degree of novelty on a numeric scale (Lee et al., 2015) and consider the dataset's local and global properties (Breunig et al., 2000). LOF's advantages over other outlier detection approaches are that LOF detects outliers concerning the density of neighboring objects, not by the global model (Pokrajac et al., 2007), and can detect outliers regardless of the data distribution (Pokrajac et al., 2007).

Therefore, in the dissertation, the local outlier factor (LOF) analysis is used to detect the rarity of patents. Table 12 explains the importance of local outlier factoring in the dissertation, the data used, and the expected result.

Table 12
Local Outlier Factoring in the dissertation

Why is Local Outlier Factoring Needed in the dissertation	LOF can calculate the degree of extremity and better compare outliers in data. To detect outliers with a higher degree of extremity or outliers
What Data is Used	Patent-Keyword Matrix, PCA results lof() function from the "*Rlof*" package in R
What are the Expected Results	A data frame of patent number, patent issued date, and the rarity value. Outlier scores = rarity in VRIN.

A text must be transformed into data points to conduct a local outlier factoring. One method is principal component analysis. Principal Component Analysis (PCA) is a multivariate data analysis that can simplify any data matrix (Wold et al., 1987). Wold et al. (1987) stated that the PCA could estimate the correlation structure of variables in the data, extract dominant patterns and show it in a plot. Furthermore, Adbi and Williams (2010) stated that the PCA aims to extract important information about the data set, reduce the data size and keep the important information, simplify the description of the data set, analyze the data and present the information by displaying it on a plot. A new variable, known as the principal component, is computed as a linear combination of the data variables (Abdi & Williams, 2010). The first principal component has the largest variance, which explains the data's largest portion. The second principal component has the second-largest variance but is computed under the first principal component (Abdi & Williams, 2010). The other principal components are calculated likewise.

Shlens (2014) highlighted that the PCA could reduce the complexity of a data set and reveal hidden and relevant information. The author highlighted that PCA has three assumptions: There needs to be a linear relationship between all variables because PCA is based on the Pearson correlation coefficient. The principal component with large variance represents important and interesting information. Principal components are solvable using linear algebra decomposition techniques.

Meng et al. (2015) examined the cluster validity between PCA and K-means cluster analysis using temporomandibular joint data. The authors stated that clustering with the PCA instead of original variables would improve the cluster quality. Moreover, the PCA has been combined with LOF in past research. Song et al. (2014) used the LOF and Multisubspace PCA to propose a new clustering strategy. Ma et al. (2016) measured the LOF of large-scale traffic data on a projected PCA domain.

It is not easy to provide an accurate definition of an outlier (Wang et al., 2019). However, in general, it can be defined as a data point that is significantly dissimilar to other data points and, thus, does not imitate typical behaviors of other data points. Furthermore, interest in outliers is high because they may contain critical and actionable information (Radovanović et al., 2014).

According to Aggarwal (2017), outliers contain useful information about the system and provide useful "application-specific insights." The author stated that an outlier of data could be abnormalities, discordant, deviants, or anomalies, and there are two types of outliers: noise and anomalies. Furthermore, data may contain a significant amount of noise, and these noises are not interesting to analysts, while anomalies may provide meaningful information (Aggarwal, 2017). The author highlighted that weak and strong outliers denote noises and anomalies in data. Noises may not provide useful information, and thus, identifying and removing noises from the data is important for mining and analysis purposes (Aggarwal, 2017). Furthermore, one way to distinguish noises and anomalies is that anomalies have a much higher "outlier" score than noises (Aggarwal, 2017).

The LOF is needed to detect the rarity of patents, and PCA is a way to transform text-based variables into a 2D plane with data points. Each point on the PCA represents a patent. LOF is a good technique to determine the patents' rarity because it can calculate the degree of extremity and better compare the outliers and anomalies in the data. Furthermore, identifying outliers can discover new and unexpected knowledge in various fields, and therefore, conducting an outlier detection is a meaningful and important task (Knorr et al., 2000). Recall that the larger the outlier scores, the higher rarity of the patent. The PCA is a good technique because it also uses a patent-keyword matrix as an input, and therefore, no new data is needed. It can also extract information, reduce data size, and simplify it. The LOF and PCA's expected results are a dataset of each patent's rarity value. Table 13 explains the importance of principal component analysis in the dissertation, the data used, and the expected result.

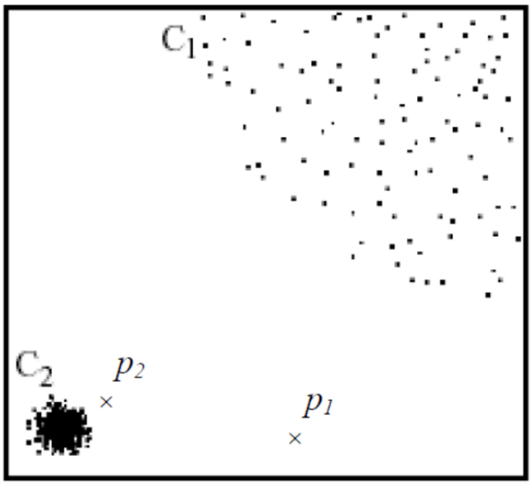
Table 13
Principal Component Analysis in the dissertation

Why is Principal Component Analysis Needed in the dissertation	To create a 2D plot/domain so that LOF can be computed
What Data is Used	Patent-Keyword Matrix recipe() function and prep() function from the "*recipes*" package in R
What are the Expected Results	A data frame of patent number, patent issued date, and the rarity value. Outlier scores = rarity in VRIN.

4.2.3.1 Understand Local Outlier Factoring

Figure 20 shows a two-dimensional plane with a dataset. There are two major clusters, C1 and C2, and outliers like P1. It is easy to notice that the distance between objects inside cluster C1 is smaller than the distance between object P2 and the nearest neighbor from cluster C2. Thus, P2 is not considered an outlier, while P1 is considered an outlier. This example shows that it is not easy to detect outliers using only the nearest neighbor's distance. In LOF, both P1 and P2 are considered outliers due to the density around the objects.

Figure 20
Two-dimensional plane of the dataset



Source. Lazarevic et al. (2003); Lee et al. (2015)

The algorithm for computing the LOF degree of all objects in the dataset follows a four-step process (Breunig et al., 2000) :

1) For each data object, q, compute the k-distance(q) as the distance to the kth nearest neighbor of q, which is defined as all points whose distance from p is not greater than the k-distance and is denoted as d(p,o) to define the distance between objects p and o. Compute the reachability distance for each data q to data p using Equation 3:

$$reach - dist_k(p, o) = maxk - distance(o), d(p, o) \qquad \text{Equation 3}$$

Note. The above equation shows the reachability distance of object p from object o, and K is a natural number.

Compute the local reachability density (lrd) of data object q as the inverse of the average reachability distance based on K or MinPts (minimum number of data objects) using Equation 4:

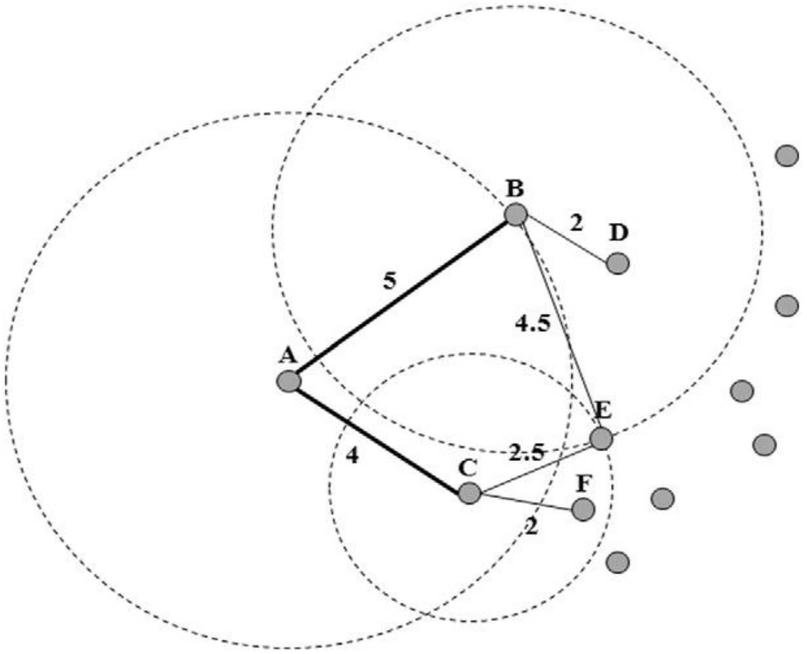
$$lrd(q) = \frac{k}{\sum_{p \in kNN(q)} r\, each - dist_k(q, p)} \qquad \text{Equation 4}$$

Compute LOF data object q as the ratio of average local reachability density of q's k nearest neighbors and local reachability density of the data object q with Equation 5:

$$LOF(q) = \frac{\frac{1}{k} \sum_{p \in kNN(q)} l\, rd(p)}{lrd(q)} = \frac{1}{k} \sum_{p \in kNN(q)} \frac{lrd(p)}{lrd(q)} \qquad \text{Equation 5}$$

If LOF(q) is 1, point q has a similar density as its neighbors. If LOF(q) is less than 1, point q has a higher density than its neighbors, and thus, it is an inlier. Finally, if LOF(q) is larger than 1, point q has less density than its neighbors, and thus, it is an outlier. Figure 21 shows an example of how to compute the LOF of point A when K is 2. The two nearest points for A are B and C.

Figure 21
Example of LOF Computation



Source. Lee et al. (2015)

The first step is to find the reachability distances. Therefore, the reachability distance of A and B, as well as A and C, are computed as follows: $reach - dist_2(B, A) = maxk - distance(A), d(B, A) = 5$ $reach - dist_2(C, A) = maxk - distance(A), d(C, A) = 5$

The second step is to compute the local reachability density (lrd). For point A, it is as follows:

$$lrd(A) = \frac{2}{5 + 5} = 0.2$$

Similarly, compute the lrd for points B and C.

For point B:

$$reach - dist_2(D, B) = maxk - distance(B), d(D, B) = 4.5$$

$$reach - dist_2(E, B) = maxk - distance(B), d(E, B) = 4.5$$

$$lrd(B) = \frac{2}{4.5 + 4.5} = 0.22$$

For point C:

$$reach - dist_2(E, C) = maxk - distance(C), d(E, C) = 2.5$$

$$reach - dist_2(F, C) = maxk - distance(C), d(F, C) = 2.5$$

$$lrd(A) = \frac{2}{2.55 + 2.5} = 0.4$$

The final step is to compute the LOF for point A.

$$\frac{1}{2}(\frac{0.22}{0.2}) + (\frac{0.4}{0.2}) = 1.56$$

4.2.4 Validation Process

4.2.4.1 Qualitative Research as a Case Study

Creswell (2015) stated five different qualitative research approaches (narrative research, phenomenology, grounded theory, ethnography, and case study). In brief, narrative research focuses on exploring the life of an individual; phenomenology focuses on understanding the essence of the experience; grounded theory focuses on developing a theory grounded in data; ethnography focuses on describing and interpreting culture-sharing groups, and a case study focuses on developing an in-depth analysis of a single case or multiple cases.

The dissertation is a case study on EV wireless charging technology patents. Therefore, conducting qualitative research as a case study approach makes sense. According to Creswell (2015), there are three types of case studies. The first type is an instrumental case study, where the researcher focuses on one issue and uses a case to illustrate the issue. The second type is a collective case study, where the research focuses on one issue, just like the instrumental case study, but uses multiple cases to illustrate the issue. Finally, the third type is an intrinsic case study, where the researcher focuses on the case itself, not on the issue. The dissertation is an instrumental case study because an issue (low number of patent royalties in South Korea compared to that of the United States) was first identified, and used EV wireless charging technology patents as a case study to examine the issue.

4.2.4.2 Model Validations

Law (2009) stated that a “valid” model could help make decisions similar to the system itself. Furthermore, the author highlighted that while it is recommended for simulation models to be validated, which Law defined as determining whether a simulation model is an accurate representation of the system, it is not often the case due to lack of time and money. In addition, the more time and money are spent on developing a model, the more validation the model will have (Law, 2009).

Sargent (2011, 2014) introduced three decision-making approaches to validate a simulation model. The first approach, the most common approach, is where the model development team validates (Sargent, 2014). It uses different model results and evaluations during the model development process. The second approach is where the users of the model validate the model. This approach is suitable for development teams that are small in size (Sargent, 2014). The third approach is called the “independent verification and validation (IV&V)” (Sargent, 2014). This approach is often used in the development of “large scale” models and uses third parties (those that are independent of development teams and model users) (Sargent, 2011). Sargent (2014) highlighted that the second and the third approaches are better validation approaches.

Sargent (2011, 2014) emphasized four types of validation in the model development process. The first is data validity. Data problem is often the reason for the failure of model validation (Sargent, 2014). Second, it is the conceptual model validation. This validation determines whether the theories and assumptions used in the model are correct and whether the model’s representation of the problem structure is reasonable (Sargent, 2014). The third is the computerized model verification. This validation examines whether the computer program and implemented model results are correct (Sargent, 2014). Finally, the last validation is operational validity. Operational validity examines whether the model has the accuracy required for the intended purpose and applicability (Sargent, 2014).

The dissertation conducts data validity by consulting with patent researchers, a librarian, and patent attorneys to validate the patent search query used to collect patent information regarding EV wireless charging technologies. The dissertation uses past research to validate the connection between VRIN and patent, as shown in the previous section, to validate the conceptual model validation and the computer model verification. In addition, the dissertation uses potential users to validate the operational validity.

4.2.4.3 Qualitative Process

According to Creswell (2015), the researcher needs to ask open-ended questions so that the interviewee can express their experiences without any external influences such as the researcher's research or past research. There are various types of interviews and open-ended questionnaires, such as one-on-one or focus group interviews, telephone interviews, email interviews and open-ended questionnaires. Table 14 describes the different types of interviews and open-ended questionnaires.

Table 14
Different Types of Interviews and Open-Ended Questionnaires

Types of Interviews and Questionnaire	Description
One-on-One	Most time consuming, but popular among educational research
Focus Group	Used to collect a shared understanding of the shared group as well as a view of specific people The size of the focus group tends to be around four to six people
Telephone	If participants are geographically dispersed and thus, unable to meet face to face Asking a small number of general questions Used a recorder to record the phone interview
Email	If participants are geographically dispersed and thus, unable to meet face to face Used to collect open-ended data Quick to access a large number of people
Open-Ended Questionnaire	Asking open-ended questions and some close-ended questions Many different answers to analyze

According to Creswell (2016), there are five steps in carrying out a qualitative process:

1) *Identify participants and sites to be studied and engage in a sampling strategy that will best help you understand your central phenomenon and the research question you are asking*
2) *Gain access to these individuals and sites by obtaining permissions (IRB)*
3) *Need to consider what types of information will best answer your research questions.*

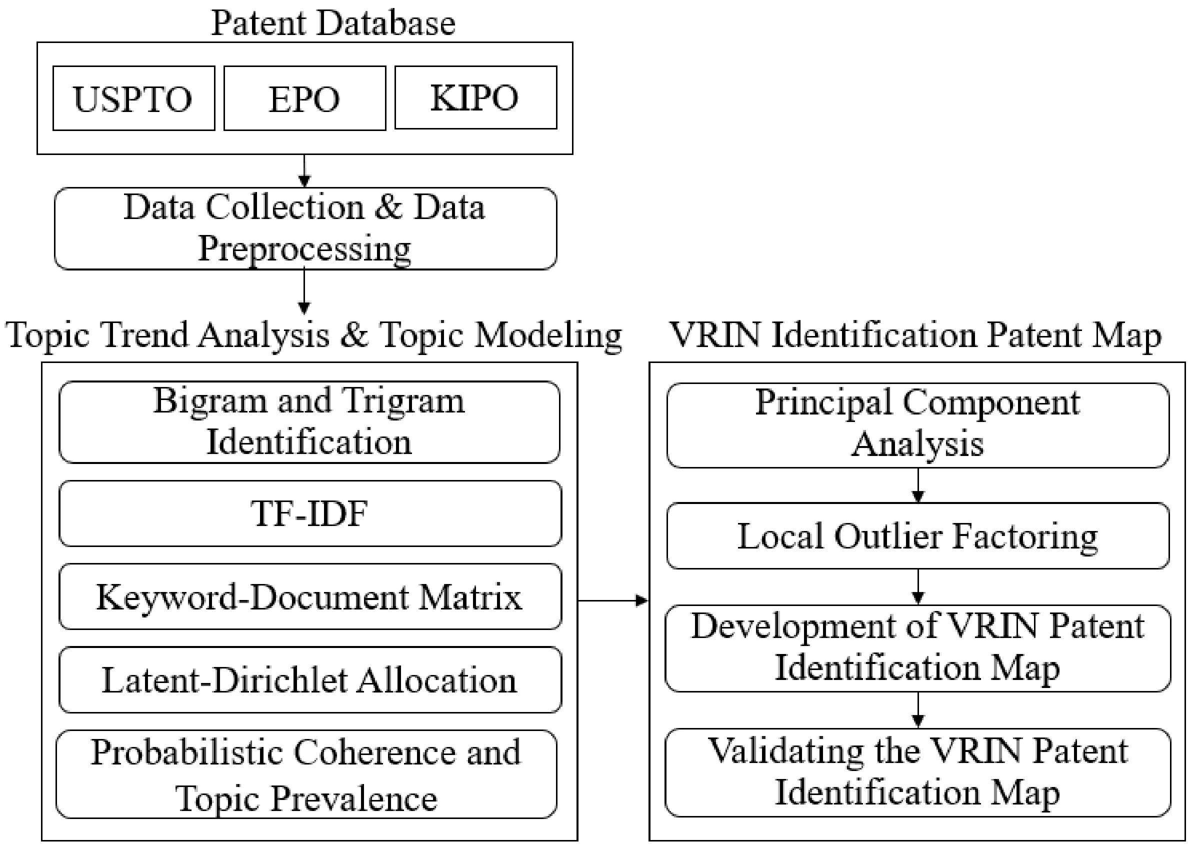
4) *Need to design protocols or instruments for collecting and recording the information*
5) *Need to administer the data collection with special attention to potential ethical issues that may arise.*

4.3 Research Approach

The dissertation integrates two research techniques, topic trend analysis using topic modeling and patent mapping, to compare the competitive advantage, in terms of VRIN attributes, of EV wireless charging patents registered in Korean Intellectual Property Office (KIPO) and compares them to similar patents in the United States Patent and Tradement Office (USPTO) and European Patent Office (EPO).

This section presents the research approach of the dissertation and is divided into seven steps. Step 1 presents how the data was collected and preprocessed for analysis. In addition, it provides evidence as to how the patent search query was formed. Steps 2 and 3 convert the corpus into a document-term matrix by identifying bigrams and trigrams and calculating the term frequency-inverse document frequency (TF-IDF). Step 4 carries out the LDA. Steps 5 and 6 carry out the principal component analysis and the local outlier factoring to calculate the outlier scores for each patent. Step 7 combines the number of forward citations, claims, and outlier scores into a patent map. Finally, Step 8 identifies the minimum sample size for the online questionnaire. Figure 22 shows the research process of the dissertation.

Figure 22
Research Process Outline



4.3.1 Step 1: Data Collection and Data Preprocessing

Step 1 is to collect the data. USPTO has the second-highest number of patents in force behind EPO and the most by a single country (Five IP Offices, 2019). In addition, USPTO patents are references far more than patents filed in other offices like the EPO (European Patent Office) (Michel & Bettels, 2001). Also, patents granted at EPO do not confer to pan-European patent protection. In other words, each country must validate patents separately to obtain the patent protection needed for that desired European country (USPTO, 2020).

Comparing the VRIN attributes of patents filed by Korean public organizations to patents in the USPTO and the EPO would provide more elaborated results. Therefore, the dissertation plans to use patents from KIPO, USPTO, and EPO. First, the dissertation compares the technology transfer activities in the EV industry in Korea and the United States. Therefore, patents in KIPO and USPTO must be analyzed. However, since there is an increase in EV patenting activities in the EPO, the dissertation also analyzes EPO patents. Second, developing a patent map using the VRIN framework is a novel approach, and therefore, focusing on a specific technology (wireless charging) instead of multiple technologies (such as charging systems and batteries) would be better in testing the methodology.

4.3.1.1 Patent Search Query Validation

Lim and Kim (2020) stated that three patents related to electric vehicles (EV) were first filed in Korea in 2008. The average number of EV patents filed per year grew between 2009 and 2011 but decreased from 2012 to 2016. From 2017 to 2019, there was an increase to 31 patents per year. Fukuzawa and Ida (2016) found that it takes, on average, six years for a patent to reach its peak in its citations. In addition, Narin and Olivastro (1993) found that citations to earlier patents peak when the patents are three to five years in age. Squicciarini, Dernis, and Crisculo (2013) examined the patent quality with several variables, including patent forward citations. The authors used patent forward citation up to five years after the patent publication. Therefore, the dissertation uses patents from 2008 to 2020 to examine the emerging trends of EV wireless charging patents and uses patents from 2008 to 2017 to develop the patent map.

Patent analysis is closely related to the patent collected through the search query. A university librarian and two patent researchers from KIPO were consulted to validate the patent search query for the dissertation. The dissertation first focused on a broad area of charging systems. However, in an email on March 3rd, 2021, the university librarian recommended focusing on a narrow technology instead of a broad technology like charging systems, consisting of narrow technologies like batteries and software. Furthermore, in a phone call interview on March 21st, 2021, one patent researcher recommended focusing on a narrower topic such as wireless charging technologies and provided a phone number to another researcher regarding wireless charging systems. Finally, in a phone call interview on March 24th, the second patent researcher provided key terms related to wireless charging and recommended using IPC code to filter out the appropriate patents. According to the patent researcher, three main IPC codes for technologies related to EV wireless charging patents are B60L[23], H02J[24], and G06Q[25].

The methodology used in the dissertation, patent mapping and topic modeling, can be conducted with other patented technologies, but the dissertation uses EV wireless charging technologies to test the applicability of the patent mapping methodology. Therefore, the following patent search query was used.

nftxt = “electric vehicle” AND (ctxt any “charg*, recharg*, energy” OR ctxt any "power, recept*, transfer, transmit“) AND (ab any”wireless, inductive, non-contact, contactless, magnetic" OR ab any “resonance, electromagnetic wave, microwave”)

Then the patent search pool was filtered, using the ESPACENET filter function, to search for patents with the following four factors. First, patents are currently published in the EPO,

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[23] Patents related to the following: magnetic suspension or levitation for vehicles, monitoring operating variables of electrically-propelled vehicles, electric safety devices for electrically-propelled vehicles, propulsion of electrically-propelled vehicles, supplying electric power for auxiliary equipment of electrically-propelled vehicles, electrodynamic brake systems for vehicles in general (WIPO, 2021c)

[24] Patents related to circuit arrangements or systems for supplying or distributing electric power, systems for storing electric energy (WIPO, 2021c)

[25] Patents related to data processing systems or methods, specially adpated for administrative, commercial, financial, managerial, supervisory or forecasting purposes, systems or methods specially adapted for administrative commerical, financial, managerial, supervisory or forecasting purposes, not otherwise provided for (WIPO, 2021c)

KIPO, or the USPTO. Second, patents with information in English so that the abstract can be analyzed. Third, patents have a publication date between January 1st, 2008, and March 24th, 2021[26]. Fourth, patents with IPC code of either B60L, H02J, or G06Q.

4.3.1.2 Data Preprocessing

Once the dataset is created, the data must go through the pre-processing stage. In text mining and natural language processing, pre-processing is considered one of the most crucial data mining phases because the data mining analysis relies heavily on the quality of data used in the analysis (Nantasenamat et al., 2009). Therefore, the pre-processing phase includes data cleaning and data transformation. Camacho-Collados and Pilehvar (2017) examined the impact of simple text pre-processing techniques, such as lower-case, lemmatization, multiword grouping, stop word removal, and tokenization. The authors found the following results. First, there is a low variance in the large training set. This result suggested that pre-processing is not important when the training data is big enough. Second, while lower-casing did help in reducing sparsity and vocabulary size, it may increase ambiguity. For example, the fruit apple and the firm Apple are considered identical when lower-casing is applied. Third, while complex text pre-processing techniques like lemmatization and multiword grouping help reduce sparsity, it does not help in text classification. Fourth, simple tokenization works equally or better than complex text-preprocessing techniques. Tokenization is a process in which a paragraph or section or a whole document is segmented into sentences, phrases, or words (Stavrianou et al., 2007).

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[26] Date of the patent collection

4.3.2 Step 2: Identifying Bigrams and Trigrams

Furnkranz (Fürnkranz, 1998) combined unigrams (single words) with word n-grams to conduct a text classification. According to the author, bigrams (two consecutive words) and trigrams (three consecutive words) helped improve the classification performance, but longer word n-grams had no beneficial impact. Majumder et al. (2002) stated that N's value is generally 2 or 3 because N-gram language models cannot estimate probabilities for all words. According to Fan and Zhang (2018), TF-IDF and unigrams with either bigrams or bigrams + trigrams showed the best result for support vector machine (SVM)[27].

The tokens() function from the *"quanteda"* package in R is used to conduct the unigram, bigram, and trigram search on the patent abstracts. As a result, unigrams, bigrams, and trigrams for each patent abstract and the frequency are extracted in a data frame format.

4.3.3 Step 3: Constructing the TF-IDF and the Document-Term Matrix

After the texts are tokenized, the next step is to examine the frequently used terms. Before conducting the LDA analysis, the basic statistical analysis, such as the occurrence of key terms, is conducted. There are two methods of calculating the occurrences of a term in text mining. First is the term frequency (tf), which calculates the number of occurrences of a term in the corpus. TF may be useful in seeing whether the term has been repeated often in the corpus; it has a clear drawback. For example, if a term appears in all patent abstracts, the word has a high TF value, but it does not add much information to the analysis. The second is the Term

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[27] SVM is often used in pattern recognition and have been used with PCA (Lin, 2018)

Frequency-Inverse Document Frequency (TF-IDF), a weighted measurement of term frequency that checks how relevant the term is throughout the corpus.

Instead of counting the terms' frequency, conducting a TF-IDF is recommended. TF-IDF is one of the most used weighting schemes in the information retrieval system and is defined as a product of term frequency and, inversely, of log scaled document frequency (Aizawa, 2003) and can classify terms into elite / non-elite words (Robertson, 2004). In other words, TF-IDF increases the weight of a term when it frequently appears in a document but also decreases the weight if that term is also found frequently in other documents (Hiemstra, 2000). Furthermore, several studies have examined and justified TF-IDF and its effectiveness (Aizawa, 2003; Zhang et al., 2011). The TF-IDF is computed with Equation 6:

$$w_{i,j} = tf_{i,j} X \log\left(\frac{N}{df_i}\right) \qquad \text{Equation 6}$$

Where w stands for the weight of the term, $tf_{i,j}$ stands for the number of occurrences of term i in document j, df_i stands for the number of documents containing the term i, and N represents the total number of documents in the corpus.

The document-term matrix is constructed because topic modeling assumes a set of keywords can define a document. Therefore, a single DTM matrix is created where each column represents a term or keyword, and each row represents a patent.

4.3.4 Step 4: Conducting the LDA

4.3.4.1 Selecting the Number of Topics, K

Step 4 is to conduct the Latent Dirichlet Allocation (LDA). The first step in LDA is to select the number of topics, K. Since the number of topics can change the results of the analysis, it is important to find the optimal value of K because an insufficient number of topics could render the LDA, and an excessive number of topics can make the LDA model too complex to interpret (Zhao et al., 2015). However, Zhao et al. (2015) highlighted that the best number of topics to create the best results of the topic modeling is unknown, and there is no way to identify the appropriate number of topics. One example of an error evaluation method for topics is the perplexity-based method, which measures how well a statistical model can explain the data (Zhao et al., 2015). However, the authors stated that while perplexity might generate meaningful results, it is unstable and can vary even for the same dataset. Thus, past studies have used trial and error evaluation (Zhao et al., 2015).

Therefore, for the dissertation, a topic number generating function, FindTopicsNumber() from the *"ldatuning"* package in R is used (Nikita, 2016). According to Nikita (2016), this function combines four metrics to find the appropriate number of topics. Griffiths & Steyvers (2004) used the Gibb sampler. Cao et al. (2009) provided a method based on topic density and minimizing the average cosine similarity between the topic distribution. Arun et al. (2010) used the minimum value of the symmetric Kullback-Liebler divergence of the corpus as a matrix factor. Deveaud et al. (2014) maximized the average Jansen-Shannon distance of the topic distribution. The optimal number of topics is calculated by minimizing the results of Arun et al. (2010) and Cao et al. (2009) results and maximizing Deveaud et al. (2014) and Griffiths & Steyvers (2004) results.

4.3.4.2 Identifying the Topics and Exploring the Results

After identifying the number of topics, the FitldaModel() function from the *"textmineR"* package in R extracts the topics and keywords. The identified topics are then explored to identify the trends in patenting activities. Finally, the current share of each topic and the change in patent share are examined to analyze the trends and identify emerging technology areas.

4.3.5 Step 5: Conducting the PCA

The next step is to create the principal component (PC) variables and plot the PCA plot. A function called step_pca() from the "tidymodels" package in R creates the principal component variables. After the variables are created, the PCA plot is created using the ggplot() function from the "ggplot2". This section aims to discover the PC1 and PC2 data points.

4.3.6 Step 6: Conducting LOF Analysis

After identifying the PC1 and PC2 variables, the next step is to conduct the local outlier factoring analysis. It consists of two steps.

4.3.6.1 Selecting the Number of Nearest Neighbors, K

As stated above, the LOF uses K-nearest neighbors in its analysis. Therefore, just like the number of topics in the LDA, it is important to find the optimal value of K to get the best result for the LOF. The classification results are sensitive to data sparseness and noisy or mislabeled data points if K is too small (Gou et al., 2012; Imandoust & Bolandraftar, 2013). Furthermore, extremely larger values of K tend to degrade the performance of the classification

(Gou et al., 2012). A method to identify the value of K is to use the training error rate and the validating error.

Similar to the number of topics in topic modeling, there is no structured method to find the best value of nearest neighbors. The rule of thumb for the number of neighbors is to use the square root of the total number of samples in the training dataset, and the number must be odd. However, one must be careful in determining the number of nearest neighbors because too small values of K can make the model very complex, and too large values of K can make the model inflexible and smooth (Dalpiaz, 2020).

Therefore, various methods have been used to find the number of K. One method uses the rule of thumb. Another method is using root mean square errors (RMSE). Dalpiaz (2020) stated that the best K is when the value can predict the best on the testing set. The author highlighted that finding the best RMSE is a valid method for finding the number of K. Root mean square error is frequently used to measure the differences between predicted values and observed value goodness of fit (Salkind, 2010). Therefore, the dissertation uses both methods to find the best number for K.

4.3.6.2 Identifying the LOF Scores

The reachability distances, local reachability densities, and the LOF score can be computed by utilizing the lof() function from the “Rlof” package in R. The LOF score is computed for each data point and is classified as an anomaly if the score is larger than one, or as an inlier, if the score is equal to or less than one.

4.3.7 Step 7: Constructing Patent Mapping

The final step is to identify patents with sustained competitive advantage through constructing a VRIN patent identification map. According to Jin et al. (2001), the easiest way to determine the local anomalies is to set a threshold for the LOF scores or select the top-n data objects. Kim and Lee (2017) used the average LOF scores for each document as the threshold value. Lee et al. (2015) used the normalized number of forward citations to represent influential patents and the normalized number of claims representing inimitable patents.

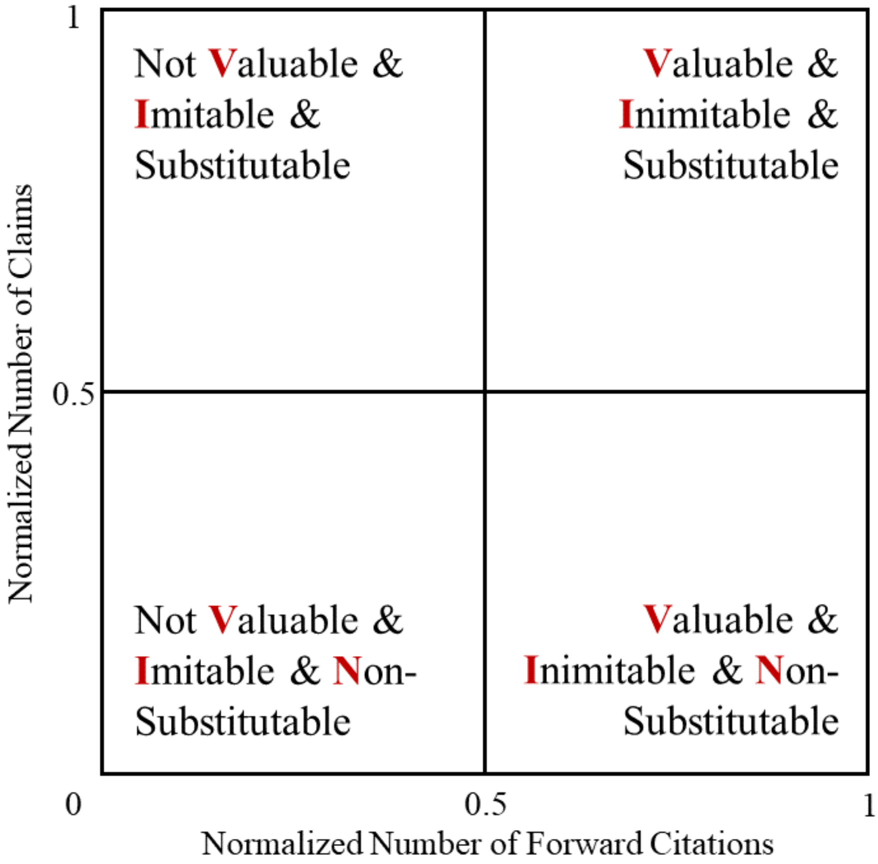
Therefore, the VRIN identification patent map uses a normalized number of forward citations and a normalized number of claims as axes and the normalized outlier scores for rarity level to ensure that the variables have the same ranges. In addition, the dissertation uses the threshold value of 50% because Deepchecks (2022) highlighted that the machine learning threshold is problem-specific and must be fined-tuned; however, in binary classification with normalized projected probabilities in the range of 0 and 1, the threshold is set to 0.5 or 50% by default.

As shown in Figure 23, the patent map uses the axes' mean value to categorize the four quadrants of patent types: Inimitable, Valuable & Non-Substitutable, Inimitable, Valuable & Substitutable, Imitable, Not Valuable & Non-Substitutable, Imitable, Not Valuable & Substitutable. The size of the points determines the rarity of the patent in terms of the normalized outlier scores. Similar to the threshold for the axes, the threshold for the normalized outlier scores is set to 0.5 as well.

Using the assumptions created in the previous section, patents with a high number of forward citations and a low number of claims are categorized as inimitable & non-substitutable.

Similarly, patents with low forward citations and many claims are categorized as imitable & substitutable.

Figure 23
VRIN Patent Identification Map Layout



4.3.8 Step 8: Validating the VRIN Patent Identification Map

Lee et al. (2015) highlighted that the patent mapping using local outlier factoring (LOF) to identify novelty patents could be a good tool to overcome past limitations that have relied only on the expert's judgment but can also be a more powerful tool if it can be integrated with other methodology like the Delphi Analysis. The authors also suggested that the patent map approach can be further examined by integrating factors like organizational expertise and resources.

The ideal validation approach for the dissertation is to analyze whether the patents identified as VRIN patents have been transferred and generated technology transfer royalties between 2018-and 2020. However, it would be difficult to conduct this validation process because detailed information such as whether a patent has been transferred is not easily accessible in Korea. Therefore, the dissertation conducts a questionnaire regarding the patent map to experts in various fields. The main purpose of the questionnaire is to assess the operational validity of the patent map.

4.3.8.1 Questionnaire Design

The dissertation designed the questionnaire according to Krosnick and Presser's (2009) eight advice for questionnaire design and six conventional ways to optimize question order. The questionnaire was created in Korean and English to collect data from a wider audience, and the English version is shown in Appendix B. The questionnaire consisted of an introduction section to explain the purpose and objective of the dissertation and the main question section of eighteen questions. The questionnaire is divided into five sections. The first section asks the experts about their field of expertise. Second, the questionnaire asks whether the experts have worked with patents. The third section examines whether the experts have any experience conducting patent analysis and their view of the drawbacks of their current methods. The fourth section examines whether the experts have heard of the competitive advantages of patents and whether the number of claims, the number of forward citations and the outlier scores are good indicators of VRIN attributes. The fifth section asks the experts about the patent map created in the dissertation, and the last section asks the experts about their thoughts about the future of EVs.

4.3.8.2 Human Research Subject and Recruitment

First, there are four types of respondents:

1) *University and public research institute TTO staff*
2) *Private and public research divisions involved in EV*
3) *Engineering, business, and law professors that conduct tech transfer and intellectual property research*
4) *Patent attorney*

These four types of respondents are appropriate because of the following reasons:

First, patent analysis is conducted to identify and predict the technology trends, determine possible infringement, and determine whether a new application of patents can be registered and published (KISTA, 2021). Researchers and university professors are examples of people interested in identifying technology trends. Also, patent attorneys and TTO staff are interested in possible infringement and whether new technology can be registered as a patent.

Second, a patent map can help managers and firms to establish effective technology development strategies (KISTA, 2021). Furthermore, it can help researchers prevent patent disputes in advance by examining other competitors' interests. These reasons are examples of why the four areas stated above are appropriate for the human research subjects for the dissertation.

Several directories were collected to create an emailing list of more than a thousand experts in various fields. A directory from the Association of University Technology Managers (AUTM) was used to get technology transfer experts and leaders, such as TTO staff patent attorneys in various areas from the United States and various European countries. A directory of TTO staff and Dankook university professors was also used to get Korean experts. In addition, directories for patent attorneys from South Korea (Korean Patent Attorneys

Association (KPAA)[28]), Europe (iaM[29]) and the United States (iaM) were also used. Therefore, a total of about 1000 experts' information was collected. Several emails were sent out using these directories to ask the experts to participate in the questionnaire.

4.3.8.3 Questionnaire Response Validation

Two methods were used to calculate the minimum sample size for the questionnaire. The first method was using an online sample size calculator. The dissertation examined several websites and its calculation and found that all used the same calculation (Equation 7).

$$Sample\ Size(n\ )\ =\ \frac{\frac{z^2 * (p(1-p))}{e^2}}{1+\frac{z^2 * (p(1-p))}{e^2 * N}} \qquad \text{Equation 7}$$

Where N stands for population size, Z stands for Z-score for the confidence interval E, e stands for margin of error, and p stands for the standard of deviation or response distribution.

Two websites were used, and the results are shown in the following figures.

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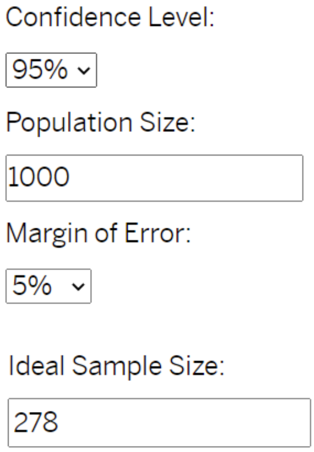
[28] https://www.kpaa.or.kr/kpaa/eng/list.do

[29] https://www.iam-media.com/directories/patent1000

Figure 24 shows the result from Qualtrics, and Figure 25 shows the result from Raosoft. Using a 5% margin of error with 1000 as the population size with a 50% standard of deviation, which gives the largest sample size, 278 responses are needed to have 95% confidence.

Figure 24
Sample Size Calculator Result



Confidence Level: 95%

Population Size: 1000

Margin of Error: 5%

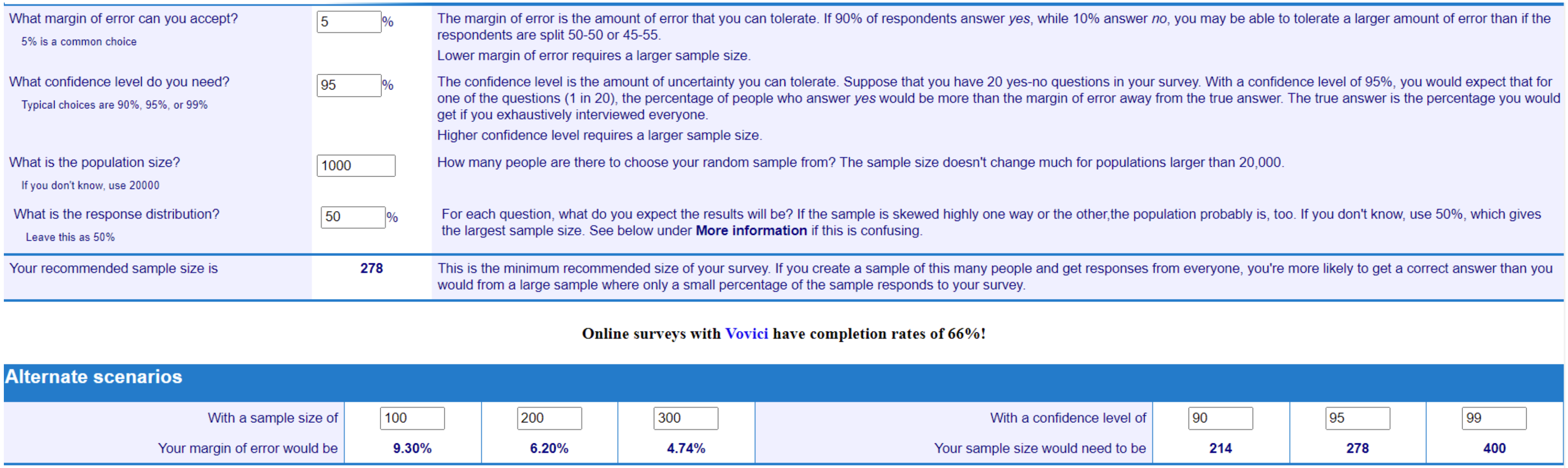
Ideal Sample Size: 278

Note. (Qualtrics, https://www.qualtrics.com/blog/calculating-sample-size/)

Another method used to calculate the sample size was using power analysis. The null hypothesis was set for the GPOWER F test studies. Memon et al. (2020) emphasized the importance of power analysis in determining the sample size. Hair et al. (2014) stated that power analysis could help determine the minimum sample size using power, effect size, and the significance level. Power, or statistical power, is defined as the "statistic ability to correctly reject the null hypothesis when it is false" and is calculated as 1-β (the probability of type II error, or false negative) (Memon et al., 2021). The larger the power, the higher likelihood of correctly rejecting the null hypothesis. Many studies highlighted that it is generally accepted when the power is 0.80 or above (Baguley, 2004; Barlett, 2021; Serdar et al., 2021). Therefore, for this research, the power is set to 0.80.

Figure 25

Sample Size Calculator Results



What margin of error can you accept? 5% is a common choice	5 %	The margin of error is the amount of error that you can tolerate. If 90% of respondents answer *yes*, while 10% answer *no*, you may be able to tolerate a larger amount of error than if the respondents are split 50-50 or 45-55. Lower margin of error requires a larger sample size.
What confidence level do you need? Typical choices are 90%, 95%, or 99%	95 %	The confidence level is the amount of uncertainty you can tolerate. Suppose that you have 20 yes-no questions in your survey. With a confidence level of 95%, you would expect that for one of the questions (1 in 20), the percentage of people who answer *yes* would be more than the margin of error away from the true answer. The true answer is the percentage you would get if you exhaustively interviewed everyone. Higher confidence level requires a larger sample size.
What is the population size? If you don't know, use 20000	1000	How many people are there to choose your random sample from? The sample size doesn't change much for populations larger than 20,000.
What is the response distribution? Leave this as 50%	50 %	For each question, what do you expect the results will be? If the sample is skewed highly one way or the other,the population probably is, too. If you don't know, use 50%, which gives the largest sample size. See below under **More information** if this is confusing.
Your recommended sample size is	**278**	This is the minimum recommended size of your survey. If you create a sample of this many people and get responses from everyone, you're more likely to get a correct answer than you would from a large sample where only a small percentage of the sample responds to your survey.

Online surveys with Vovici have completion rates of 66%!

Alternate scenarios

With a sample size of	100	200	300	With a confidence level of	90	95	99
Your margin of error would be	**9.30%**	**6.20%**	**4.74%**	Your sample size would need to be	**214**	**278**	**400**

Note. Used an online sample size calculator from Raosoft (http://www.raosoft.com/samplesize.html)

The significance level is the same as the p-value from statistics. The p-value is also known as the alpha, which is the probability that the null hypothesis is true. Alpha is conventionally set to 0.05 (Barlett, 2021). The effect size is the actual difference between two variables or groups or the strength of the association between two variables and is interpreted in Cohen's d (Barlett, 2021). Cohen (1988) provided guidelines such as small (0.2), medium (0.5), and large (0.8) so that researchers can use them when interpreting the effect size. Table 15 shows the threshold for interpreting effect size depending on the type of test. There have been many cautions regarding the use of the guideline because the effect size differs by field. For example, a large effect size in one field may be considered a small effect in another field. Nevertheless, many studies have used Cohen's guidelines as effect size (Baguley, 2004; Barlett, 2021, Memon et al., 2021).

Table 15
Effect size threshold for different tests

Test	Effect Size Threshold			
	Small	Medium	Large	Very Large
Standardized Mean Difference	0.20	0.50	0.80	1.3
Correlation	0.1	0.30	0.50	0.70

Source. Ellis (2010)

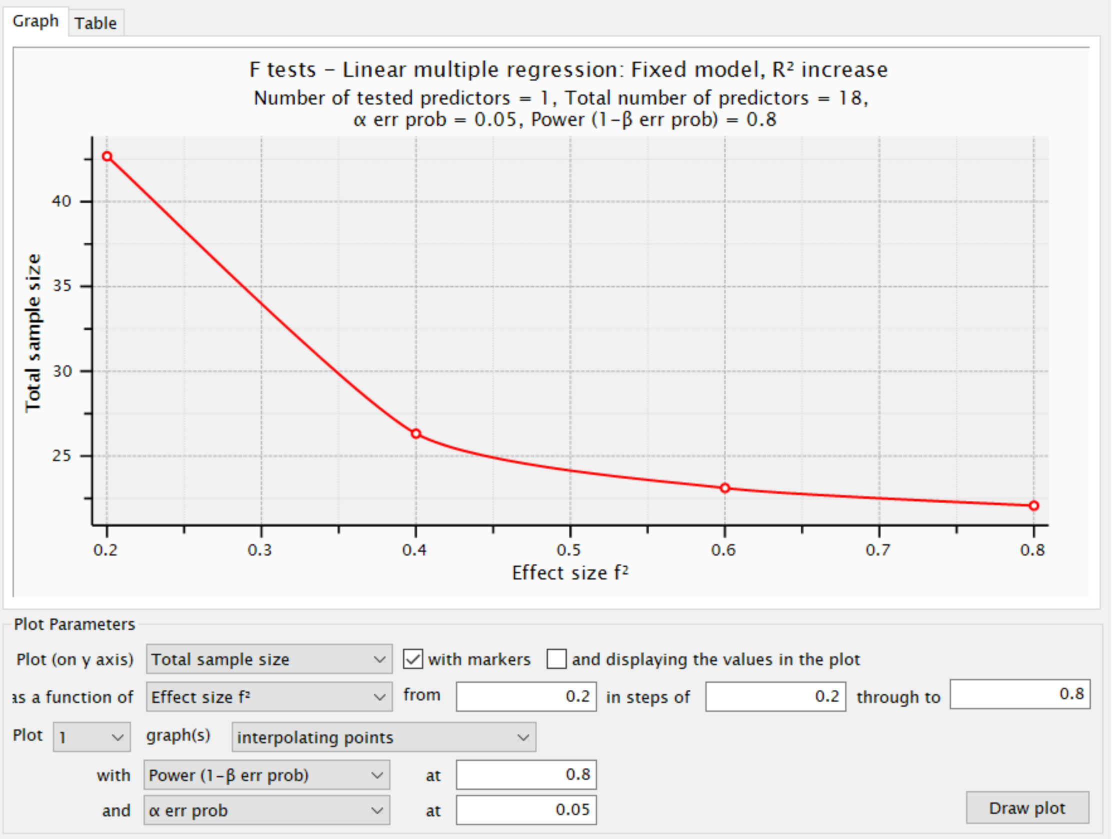
There is a direct relationship between sample size, power, effect size and significance level; in other words, if three of the four variables are known, the last variable can be calculated (Barlett, 2021). Barlett (2021) highlighted that a priori power analysis is performed to calculate the minimum sample size.

One of the most commonly used power analysis programs is GPOWER (Erfelder et al., 1996). GPOWER can compute the sample size for a given effect size, alpha level and power value and display a graph showing the different sample sizes for a range of effect sizes.

According to Professor Rice from Miami University, the appropriate parameters for conducting a questionnaire's sample size is using the F-Test's linear multiple regression: fixed model R2 increase option, with a priori type. The power was set to 0.8, the alpha level to 0.05, the total number of predictors was 18 to match the number of questions in the questionnaire, the number of target predictors to 1, and the effect size from 0.2 (small) to 0.8 (large). Therefore, these parameters were set to plot the minimum number of responses, as shown in Figure 26.

Figure 26

GPOWER result to test tout effect size from 0.2 to 0.8



Plot (on y axis) Total sample size ☑ with markers ☐ and displaying the values in the plot

as a function of Effect size f² from 0.2 in steps of 0.2 through to 0.8

Plot 1 graph(s) interpolating points

with Power (1−β err prob) at 0.8

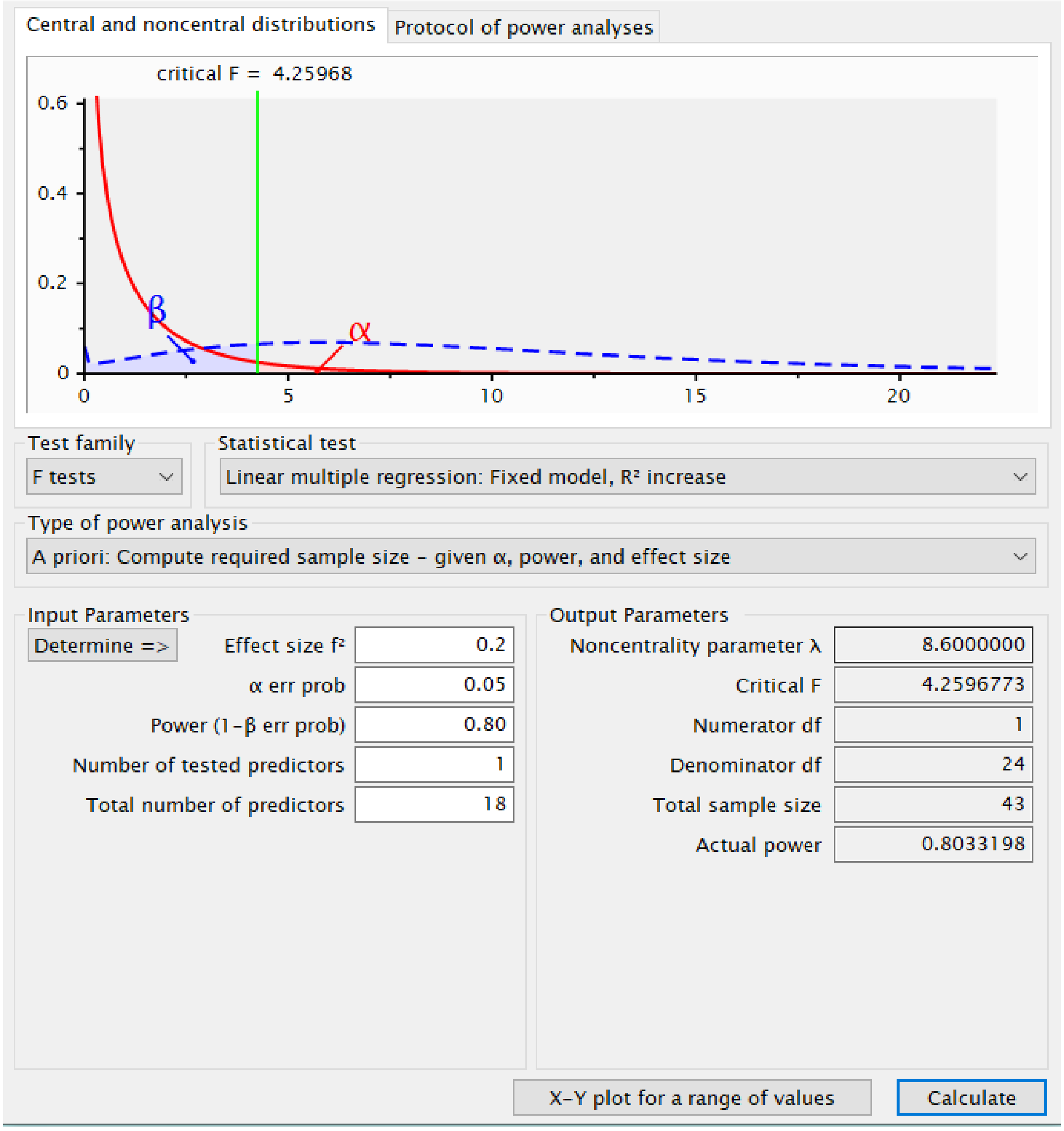
and α err prob at 0.05

According to the result of GPOWER, the sample size (number of responses) for a questionnaire with eighteen questions should range from 23 (when the effect size is 0.8) to 43 (when the effect size is 0.2, Figure 27). According to Roscoe (1975), while some experimental research may be conducted with samples between 10 to 20, 30 or more are recommended.

Furthermore, a sample size between 30 to 500 at a 5% confidence level is generally sufficient (Delice, 2010). Therefore, the dissertation aims to collect at least 43 responses.

Figure 27

GPOWER results for effect size 0.2



Test family: F tests

Statistical test: Linear multiple regression: Fixed model, R² increase

Type of power analysis: A priori: Compute required sample size – given α, power, and effect size

Input Parameters

Effect size f² 0.2
α err prob 0.05
Power (1–β err prob) 0.80
Number of tested predictors 1
Total number of predictors 18

Output Parameters

Noncentrality parameter λ 8.6000000
Critical F 4.2596773
Numerator df 1
Denominator df 24
Total sample size 43
Actual power 0.8033198

Chapter 5 Research Outcomes

5.1 Introduction

Using the research techniques and approach presented in the previous chapter, this chapter presents the research outcome, tests the hypotheses stated in Chapter 2 and answers the research questions. The chapter is divided into seven sections. Section 5.2 presents the data used in the dissertation and how the EV wireless charging patents are collected and preprocessed. Section 5.3 answers the first research question by presenting the Latent Dirichlet Allocation results. Finally, the section identifies the important topics of the EV wireless charging patents and the changing of topics in the patent abstracts.

Section 5.4 uses the principal component analysis and local outlier factoring to identify the outlier scores, which is the rarity level identified in the dissertation. Next, using the outlier scores, the number of forward citations, and the number of claims, a patent map is constructed and presented in Section 5.5. The created patent map is then validated through an online questionnaire, and the validation results are presented in Section 5.6. Finally, the chapter ends with a discussion section to examine whether the hypotheses presented in Chapter 3 are supported or not.

5.2 Data and Preprocessing

5.2.1 Patent Data

Through their ESPACENET database, EPO provides a service for users to collect patent information by downloading an excel file of the searched patents. The ESPACENET has an advantage as it allows users to search for patents from all three databases (EPO, KIPO, and USPTO) for free but only allows the users to collect limited information such as patent number, patent title, and publication date. Therefore, web crawling was programmed to gather patent data needed in the dissertation from the Google Patent Website using the patent number found through ESPACENET. Since the Google Patent Website only shows published patents, the dissertation examined EV wireless charging-related patents published between January 1st, 2008, and March 24th, 2021 (the day the patents were collected).

Using the search query and filtering the patent search pool, the dissertation found 3988 patents (1089 KIPO, 2295 USPTO, and 604 EPO). As stated above, the first Korean EV-related patents were filed in 2008. Therefore, the dissertation analyzes the patents from 2008 to 2020 to conduct the topic modeling to examine the emerging trends in the EV wireless charging technologies and patents from 2008 to 2017 to conduct the patent mapping. After the data collection, the dissertation examined patents with the same patent abstract but different publication dates. In this case, a patent with an earlier publication date was used, and newer patents with the same abstracts were discarded. Therefore, 3967 patents (1083 KIPO patents, 2284 USPTO patents, and 600 EPO patents) were used to analyze EV wireless charging technology trends. Thus, 2883 patents (744 KIPO patents, 1645 USPTO patents, and 494 EPO patents) are used for the patent mapping.

Patent offices receive and register patents from global assignees. While the dissertation could have focused on just Korean assignees for KIPO, US assignees for USPTO and European assignees for EPO, it did not filter the assignees because the number of patents would have decreased. In addition, while EVs can include passenger vehicles, trucks & vans, buses and two-three-wheelers, the dissertation did not search for EV wireless charging for different types of vehicles. Therefore, the type of patent assignee was broken down just for KIPO patents to analyze public vs. private organizations. The dissertation labeled patents that Korean universities and public research institutes filed as public organizations (kr_pub) and other Korean assignees (individuals, companies) as private organizations (kr_prv). By analyzing the patent assignees, 233 patents were filed by public organizations, and private organizations filed 511 patents. Table 16 shows the breakdown of the patent database and the total number of patents used for analysis.

Table 16

Breakdown of Patent Database and the Total Number of Patents

Search Query*
nftxt = "electric vehicle" AND (ctxt any "charg*, recharg*, energy" OR ctxt any "power, recept*, transfer, transmit") AND (ab any "wireless, inductive, non-contact, contactless, magnetic" OR ab any "resonance, electromagnetic wave, microwave")*
Filtered – English patents filed in USPTO, EPO, and KIPO with IPC codes of B60L, H02J, and G06Q and Published between Jan. 1st, 2008 and March 24th, 2021

Patent Database	**Total Number of Patents Collected**	**Patents Filed From 2008-2020**	**Patents Filed from 2008-2017**	
KIPO	1089	1083	744	Public Assignees (kr_pub) - 233
				Private Assignees (kr_prv) – 511
USPTO	2295	2284	1645 (int_us)	
EU	604	600	494 (int_ep)	
Total	3988	3967**	2883***	

* In the search query, nftxt means “all text fields or names,” ctxt any means “any of the following text in the title, abstract or claims,” ab any means “any of the following texts in abstract”

**The number of patents that are used to conduct the topic modeling

***The number of patents that are used to develop the patent map

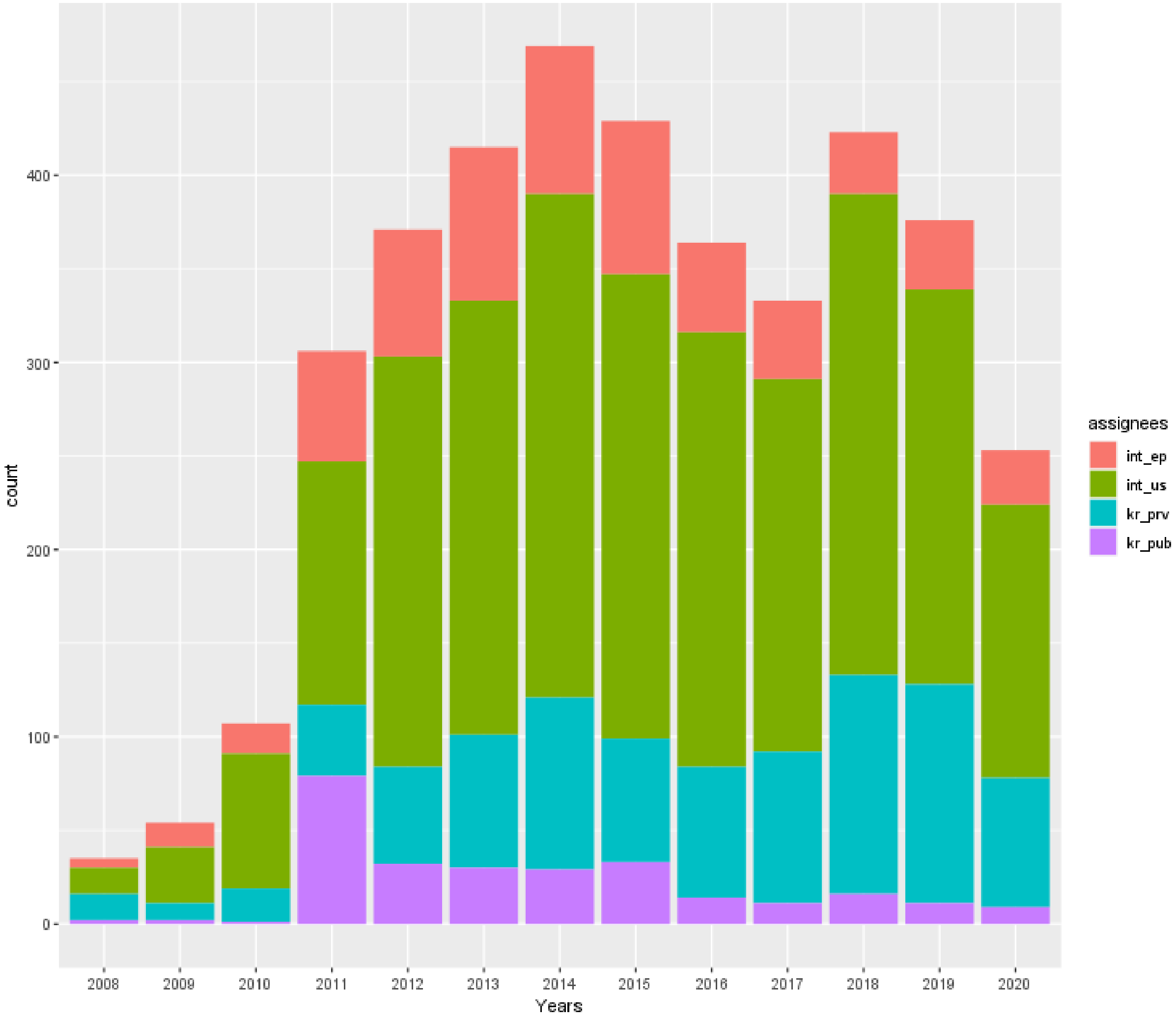
Note. The patents were collected on March 24th, 2021.

Before conducting the analysis, some basic features of the data were examined. Figure 28 shows the EV wireless charging-related patent activities between 2008 and 2020. Firstly, the number of EV wireless charging-related patents has significantly increased since 2010. This significant increase in the EV wireless charging patents implies that the technology development of electric vehicles and charging systems began before 2010 since it takes a few years for a patent to be granted. Furthermore, the number of EV wireless charging patents peaked in 2014. Interestingly, 2014 was the year when Tesla's CEO, Elon Musk, issued a statement, "All Our Patent Are Belong To You," and opened up their patent sources in hopes of speeding up the EV market. In addition, it is a bit surprising that the number of EV wireless patents decreased in 2020 compared to that in 2019.

Secondly, the assignee group information can help understand Korean public organizations' patent activities compared to other assignees. For example, the USPTO had the largest proportion of patents granted per year. Notably, the number of EV wireless patents for Korean public organizations peaked in 2011 and continued to decrease, while the number of patents for Korean private organizations increased from 2008 to 2019. In addition, despite EPO's statement regarding a peak in EV-related patent activities between 2011 and 2017, there were less than 100 patents related to EV wireless charging technologies granted per year during the period.

Figure 28

Distribution of the patent publications between 2008-2020



The number of EV wireless charging patents for analysis may seem low compared to 14,000 global patents filed in 2020 alone, according to Leach (2021). One reason for the low number of patents on EV wireless charging might be because wireless charging is not widely available to the public and is still an "immature" technology. The dissertation examined past research that is highly cited to see whether the number of EV wireless charging patents found are reasonable to be used for patent mapping analysis. Yoon et al. (2002) used 193 USPTO patents, while Lee et al. (2009) used 141 USPTO patents. Son et al. (2012) used 754 patents, and Lee et al. (2015) used 649 patents.

5.2.2 Data Preprocessing

The texts from the patent abstracts are cleaned by tokenizing them into words. During the tokenization, simple text pre-processing techniques like lower-casing and stop-word removal are implemented to contain essential words to describe the patents. For example, additional stop words such as ordinal numbers and the term “power” due to the excessive count compared to the other term. Table 17 shows functions that were used for data preprocessing and text cleaning.

Table 17
Functions Used for Data Preprocessing and Text Cleaning

Actions	Functions
Numbers Removal	tokens(remove_numbers=TRUE, remove_punct=TRUE, remove_symbols=TRUE, split_hyphens=TRUE)
Punctuation Removal	
Extra Space Removal	
Stop-words Removal	tokens_remove(stopwords("english")) tokens_remove() for specific word removal
Single Letter Word Removal	tokens_remove("\\b[A-z]\\b{1}")
Stemming	tokens_wordstem()

After preprocessing and cleaning, n-grams are identified and tokenized. The dissertation identified unigrams (1-grams), bigrams (2-grams), and trigrams (3-grams) from the corpus. Through the tokenization of 3,967 patent abstracts, 260,031 features/terms were found. The features were then transformed into a document-term matrix (DTM), a data frame that lists the occurrence of all terms in the document (patent) corpus. In the DTM, the patents are represented by rows and terms by columns. If a term is presented in a particular patent abstract, then the matrix entry corresponding to that term and patent shows the number of times that term shows up. A term may be rarely used throughout the corpus and might not provide much meaningful information for the analysis. By removing these less useful words or so-called “sparse terms,” the sparsity of the DTM can be reduced. The initial DTM had 1,030,958,076 sparse entries, compared to 587,901 non-sparse entries, which equaled to 99.9% sparsity. In text mining, terms with sparsity higher than 97% were removed by the rule of thumb. The trimmed DTM, therefore, had 1,072,290 sparse entries and 101,942 non-sparse entries.

5.3 Topic Modeling and Latent Dirichlet Allocation

Based on the document-term matrix for patent abstracts, the dissertation performed the LDA to identify topics in the EV wireless charging-related patents and examine the changing trends in the EV wireless charging technologies between 2008 and 2020. Before conducting the LDA, the keywords of the patent abstracts were analyzed.

5.3.1 Keywords Analysis

5.3.1.1 Term Frequency

While simple term frequency counts the number of terms in the whole corpus, the TF-IDF allows the user to find important words for each patent by decreasing the weight of commonly used terms and increasing the weight of terms that are not commonly used throughout the corpus. Therefore, terms with high TF-IDF values are important but not too common. For example, Figure 29 shows a visualization comparing frequency count for the simple term frequency method and the TF-IDF method of the patent abstracts. While (stemmed) terms such as “charg,” “electr,” and “vehicle” are the top three terms for the simple term frequency method, “coil” and “charg” are the top two terms in the TF-IDF method. However, there seem to be no major differences between the two methods.

Figure 29

Comparing a) Simple Term Frequency and b) TF-IDF of patent abstracts

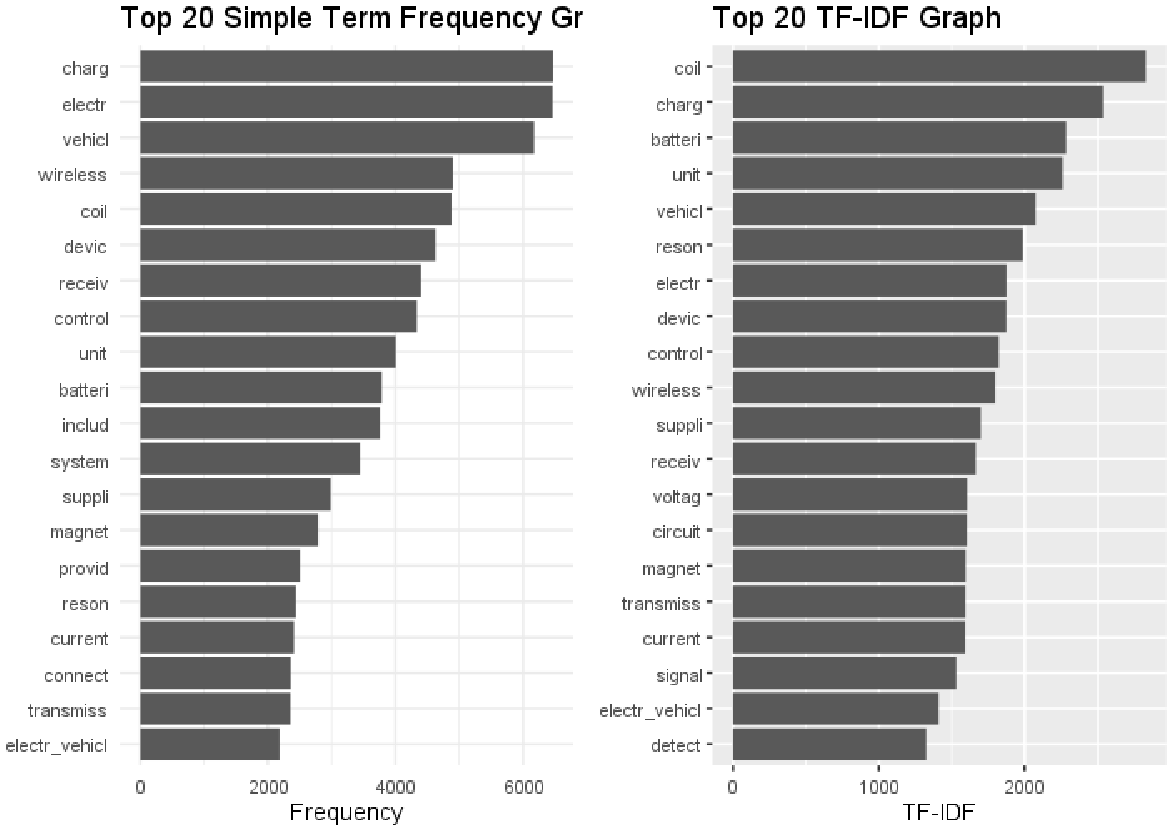
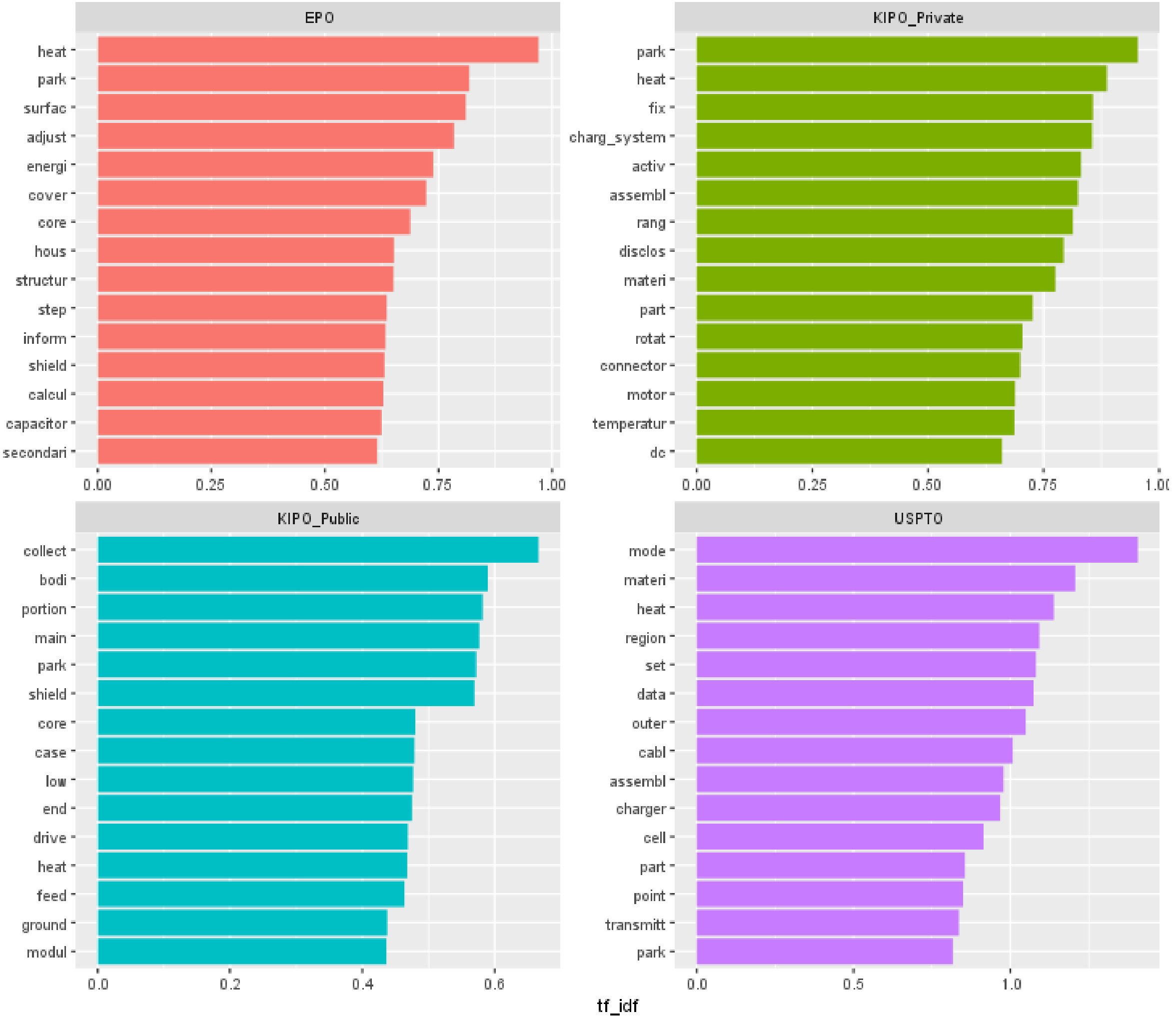


Figure 30 shows the top 15 TF-IDF terms according to each assignee type. There are three interesting analysis results. Firstly, it is noteworthy that two terms showed up in all four databases. For example, “heat” is one of the top five terms in EPO, KIPO-Private, and USPTO patents, while it is ranked twelfth in KIPO-Public patents. In addition, “park” is ranked in the top five for EPO, KIPO- Private and KIPO-Public patents, and ranked fifteenth for USPTO patents.

Secondly, the top 15 terms in the USPTO and KIPO-Private patents showed similarities, while EPO patents showed similarities to KIPO-Public patents. For example, while terms “assembl” and “materi” are ranked in the top fifteen for both USPTO and KIPO-Private patents but not in the EPO and KIPO-Public patents. Similarly, “core” and “shield” are ranked in the top fifteen for EPO and KIPO-Public patents but not in the USPTO and KIPO-Private patents. Thirdly, when all four databases are combined, nine out of the top 15 terms are the top TF-IDF terms. On the other hand, fourteen of the top fifteen TF-IDF terms for KIPO-Public patents are ranked at the bottom.

Figure 30
Top 15 TF-IDF terms by assignee types



5.3.1.2 List of Keywords

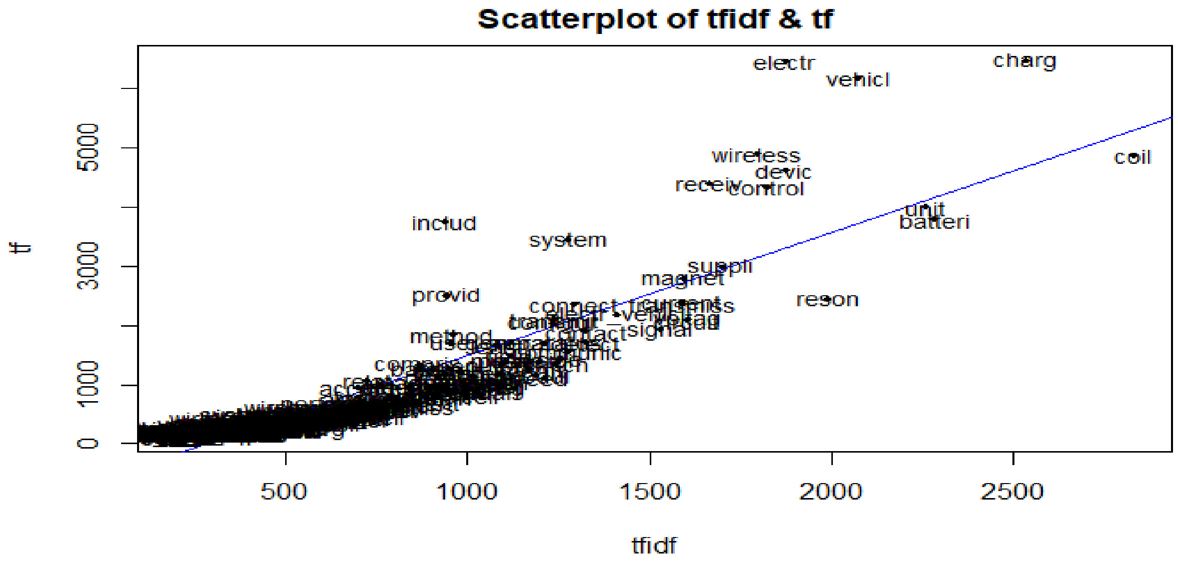
A list of keywords can be created by combining the top terms in the simple term frequency and TF-IDF. Table 18 shows the final list of twenty-four keywords generated by the term frequency and TF-IDF.

Table 18
List of Keywords based on term frequency and TF-IDF

"charg", "electr", "vehicl", "wireless", "coil", "devic", "receiv", "control", "unit", "batteri", "includ", "system", "suppli", "magnet", "provid", "reson", "current", "connect", "transmiss", "electr_vehicl", "voltag", "circuit", "signal", "detect"

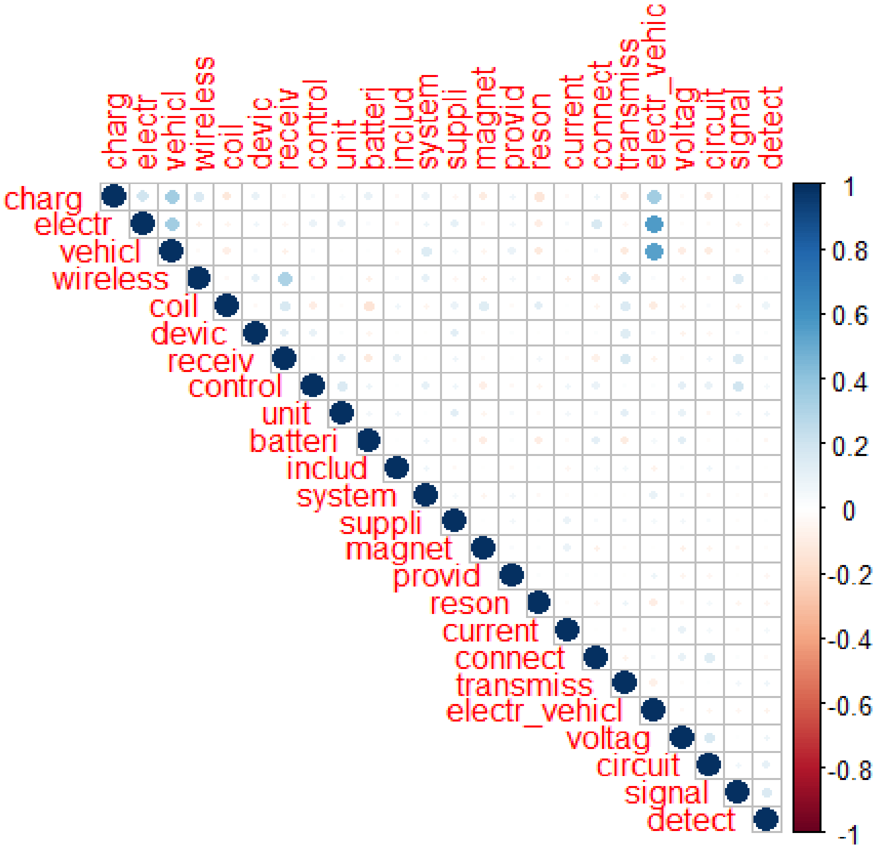
Another method to find the list of keywords is by creating a scatterplot of term frequency, and TF-IDF can help quickly examine the frequency results and identify important words. Figure 31 shows the scatterplot of TF-IDF vs. term frequency. The scatter plot of TF-IDF vs. term frequency represents the distinctiveness of weighted measures. Significant words are terms that are close to the blue line. Therefore, terms such as "electr," "vehicl," and "charg," which were the top three terms for simple term frequency, may not be as significant in keyword identification.

Figure 31
Scatterplots - a) term frequency vs. document frequency and b) TF-IDF vs. term frequency



Finally, the associations among the keywords are examined using Pearson's correlation method and correlation plot. Figure 32 shows the correlation among key terms in a plot. The correlation plot shows a positive correlation among the keywords in a blue-colored dot and a negative correlation, which means that if the frequency of one term increases, the frequency of the other term decreases in a red-colored dot. Identifying and eliminating correlated terms in the corpus is important because it provides a better result in identifying the top-ranked topics. These top-ranked topics are important when the dissertation examines the changes of topics by year to examine the trends of patents. The dissertation found that the most correlated terms are n-grams. For example, the term "electr_vehic" shows a high correlation with the terms "electr" and "vehicle," but mostly no correlation with other keywords. Therefore, the dissertation removed highly correlated terms from the corpus.

Figure 32
Correlation plot for key terms



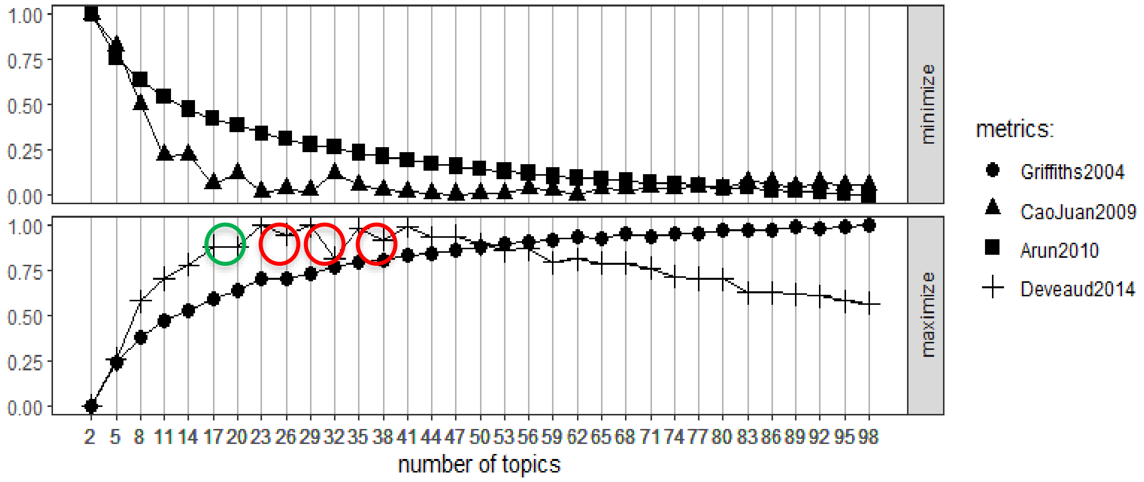
5.3.2 LDA Analysis

5.3.2.1 K-Selection, the number of topics

This section conducts a topic modeling using an LDA method to examine the patent abstracts. The first step in conducting the LDA analysis is determining the number of topics, K. Before conducting the FindTopicsNumber function, the document-term matrix is divided into training and testing data, with a ratio of 8:2. Figure 33 shows the visualization of the *FindTopicsNumber*() function from the "ldatuning" package for topics 0 to 100. As stated in Chapter 3, the best number of topics is chosen by minimizing CaoJuan2009 and Arun2010 values and maximizing Griffifths2004 and Deveaud2014 values. In the graph, there are four possibilities of K where CaoJuan2009 and Arun2010 are minimized, and Griffifths2004 and Deveaud2014 are maximized. As stated in the previous section, too many topics make the model too complex; therefore, the dissertation decided to use the smallest possible number of topics (green circle), 23.

Figure 33

Selecting the Optimal K, the number of topics



5.3.2.2 LDA Results

Several methods can transform text data into a set of topics that describe the corpus. One of the most popular methods is called the Gibbs sampling. A Gibbs sampling finds the conditional probability distribution of a single word topic assignment conditioned on the rest of the corpus (Boyd-Graber, 2018). Gibbs sampling can be applied to create a Markov Chain to create a posterior distribution on topics (Daud et al., 2010). Moreover, Daud et al. (2010) examined thirty-three studies of topic modeling their applications. Surprisingly, seventeen studies have used Gibbs sampling to conduct the topic modeling. In addition, a study that focused on discovering topics and topic evolution over time used the Gibbs sampling approach (Daud et al., 2010). Therefore, the dissertation uses a 23-topic model using Gibbs sampling to examine the distribution of latent topics and the topic evolution between 2008-2020 and is created using FitldaModel() function from the "*textmineR*" package.

As a result of an LDA topic modeling using a Gibbs sampling approach, 23 topics (as shown in Table 19) are identified. Using the distribution over words in a topic, the top terms most likely to occur in each topic are presented in the table. The labels for the topics are created using the *LabelTopics*() function from the "*textmineR*" package, a naïve topic labeling tool based on probable bigrams. Initially, some topics had labels that overlapped. For example, topics 2, 3, 5, and 8 had "electric_vehicle" as their label.

Similarly, topics 13 and 14 are labeled "power supply." Each topic needs to represent a unique theme; therefore, there must be 17 different labels. The dissertation examined all six topics and their top terms and renamed their labels.

Table 19

Top Terms for all 23 topics

Topic	Label	Top Terms
1	magnetic_induction	field, magnetic, magnetic_field, object, coil, pad, detection, signal, apparatus, configured, detecting, transfer, inductive, system, power_transfer
2	electric_vehicle	vehicle, driving, power, unit, electric, control, signal, road, receiving, fuel, information, autonomous, state, system, traveling
3	communication	information, communication, device, wireless, vehicle, control, data, user, wireless_communication, system, server, method, based, network, terminal
4	near_field	coil, primary, secondary, resonant, power, resonance, primary_coil, electromagnetic, secondary_coil, resonant_coil, induction, unit, vehicle, frequency, impedance
5	charging	charging, electric, vehicle, electric_vehicle, wireless, wireless_charging, power, battery, charger, system, method, unit, charging_system, charging_device, parking
6	batteries	battery, voltage, relay, state, switch, circuit, contact, charge, high, power, high_voltage, connected, current, main, voltage_battery
7	magnetic_resonance	coil, magnetic, core, direction, flux, coils, magnetic_flux, conductive, ferrite, winding, material, wire, formed, structure, arranged
8	connector	contact, portion, connector, charging, housing, surface, body, vehicle, connection, cover, side, member, cable, terminal, plug
9	power	power, coil, receiving, feeding, power_receiving, power_feeding, circuit, transmitting, receiving_coil, power_transmitting, device, resonance, power_receiving_coil, frequency, feeding_coil, transmission, transmitting_coil, power_transmission, coil_power, coupling, side, ac
10	battery_module	battery, heat, cooling, module, plate, contact, cells, pack, surface, assembly, member, thermal, modules, battery_pack, circuit
11	power_conversion	voltage, power, dc, current, ac, output, converter, circuit, inverter, connected, input, alternating, frequency, alternating_current, rectifier

12	electrodes	electrode, battery, electricity, layer, negative, material, electrolyte, secondary, positive, aqueous, cell, negative_electrode, cathode, surface, current
13	far_field	contact, antenna, power_receiving, side, power_transmission_coil, reception_coil, supply_system, reception, supply_device, device, system, power_supply, coil, transmission, supplying
14	power_feeding	current, magnetic, power, vehicle, field, electric, device, magnetic_field, collector, supply, generated, road, electromagnetic, core, collecting
15	control_unit	unit, signal, control, circuit, switching, control_unit, power, voltage, configured, input, switching_unit, output, communication, current, sensor, apparatus
16	charging_station	vehicle, charging, station, charging_station, charge, wireless, position, device, system, location, inductive_charging, electric, electric_vehicle, signal, parking
17	battery_management	battery, cell, system, plurality, module, management, battery_cell, pack, cells, connected, battery_pack, management_system, signal, wireless, battery_management
18	wireless_power_transfer	power, wireless, wireless_power, transmission, receiver, apparatus, power_transmission, wireless_power_transmission, transmitter, transfer, power_receiver, method, power_transfer, receiving, wireless_power_transfer
19	electric_motor	magnetic, wheel, rotor, motor, electric, stator, vehicle, magnet, rotating, shaft, drive, generator, driving, force, direction
20	energy_storage	energy, electrical, system, storage, device, electric, power, vehicle, energy_storage, inductive, electrical_energy, vehicles, source, devices, electrically
21	electromagnetic_resonators	resonator, source, power, electromagnetic, configured, electromagnetic_resonator, source_resonator, coupled, magnetic_field, wireless, device, system, field, resonators, load
22	motor_controller	motor, control, vehicle, drive, electric, torque, driving, state, engine, mode, braking, speed, device, current, controller
23	power_transmission	power, unit, device, transmission, electric_power, power_transmission, receiving, electric, reception, power_reception, power_receiving, transmitting, transmission_device, receiving_device, power_transmission_device

Topic 1, previously labeled as magnetic_field by the labeltopic() function, is changed to "magnetic_induction" because the terms like inductive, magnetic, and magnetic field relate to magnetic induction. Topic 2, which had the same label as topics 3, 5, and 8, is labeled as "electric_vehicle" because electric, vehicle, driving, and autonomous are good explanations of electric vehicles. Topic 3, formerly named "electric_vehicle," is changed to "communications" as the terms explain transferred and communicated information. Topic 4, labeled as primary_coil by the topic labeling function, is changed into "near_field" because the terms such as resonance, coil, and induction represent contactless near field power transmission. Topic 5 refers to charging an electric vehicle in general, as the terms such as the battery, charger, system, parking, and charging device are grouped. Topic 6 was formerly labeled as high_voltage but was recoded to "batteries" because the battery, voltage, temperature, load, and low are included. Topic 7 was initially "magnetic flux" but changed to "magnetic_resonance" because magnetic resonance is related to magnetic resonance (Imura, 2017). Finally, topic 8 is delineated by terms related to connectors, while Topic 9, previously labeled as power_receiving, is recoded as "power" because the terms such as transmission and AC are included.

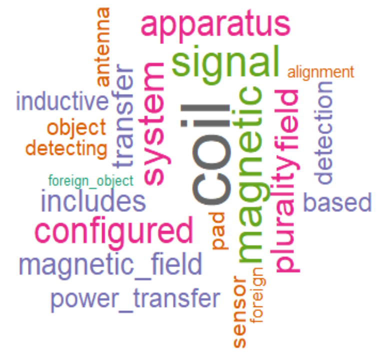
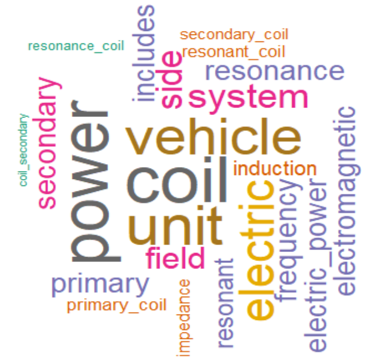
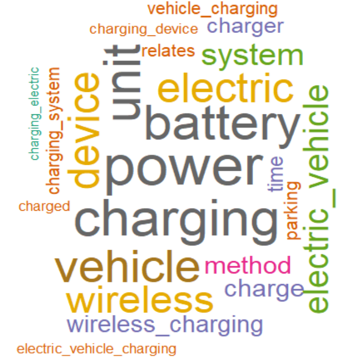
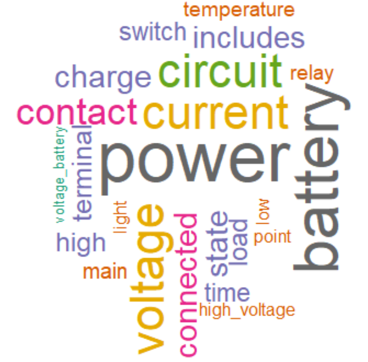
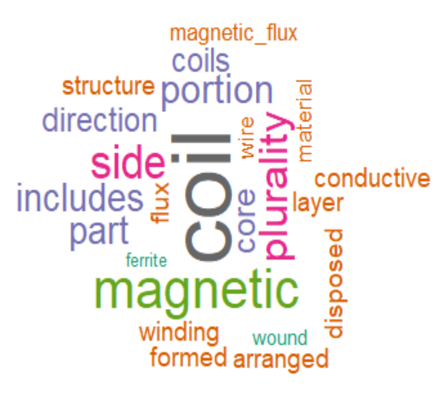
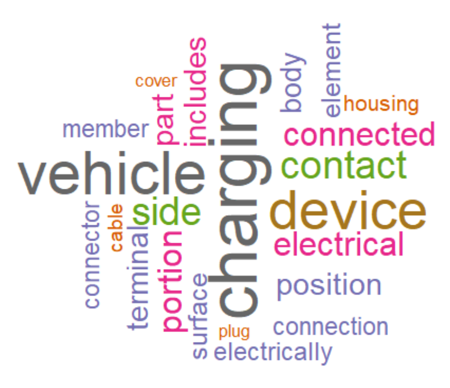
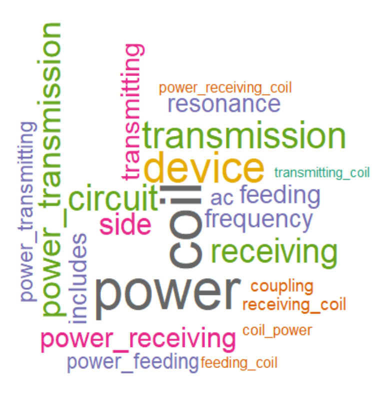
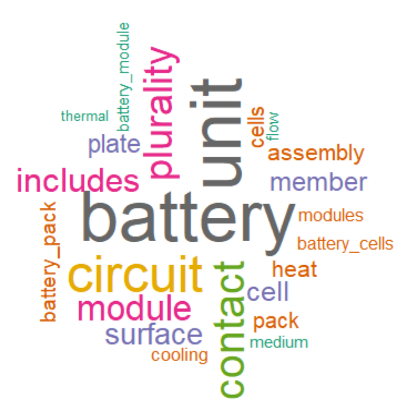
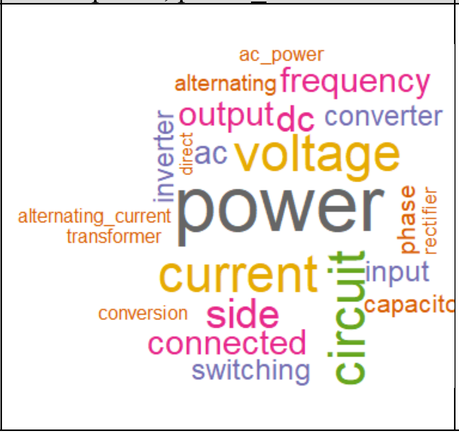
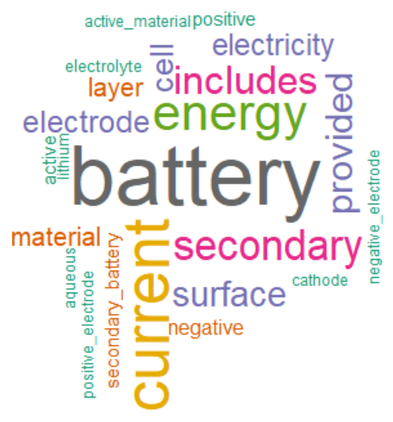
Topic 10 was labeled battery_pack but was recoded as battery_module because terms such as the battery, cell, module, and plurality explain the battery module. Topic 11, first labeled as alternating_current (AC), is recoded as "power_conversion" because terms such as DC, AC, converter, switching, and phase were included. Topic 12 was labeled as a negative electrode but changed to "electrodes" because terms such as positive electrode, cathode, surface, and lithium were included. Topic 13 was originally labeled as "power_supply" but is recoded as "far_field" because terms such as antenna, transmission coil, supply system and power supply device represent contactless far-field power transmission.

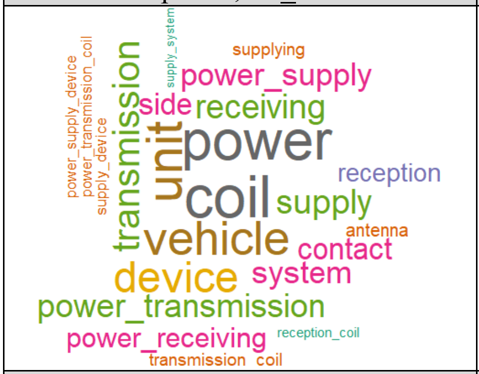
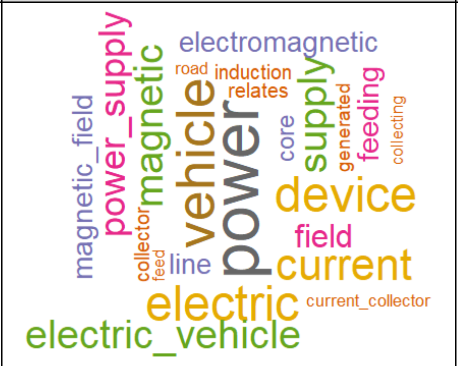
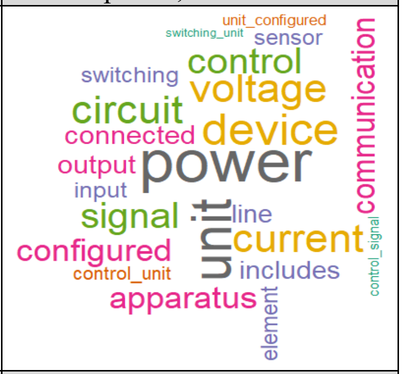
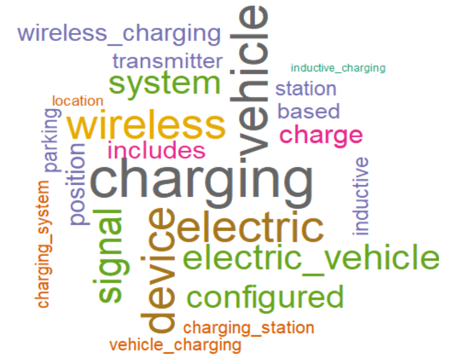
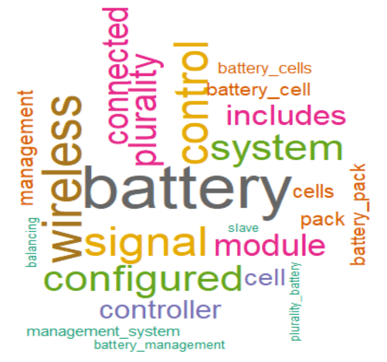
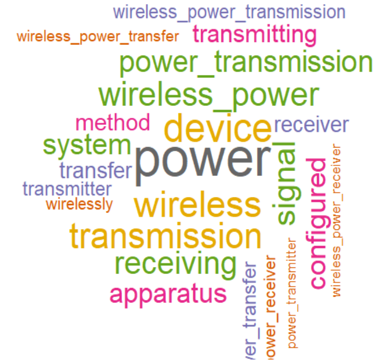
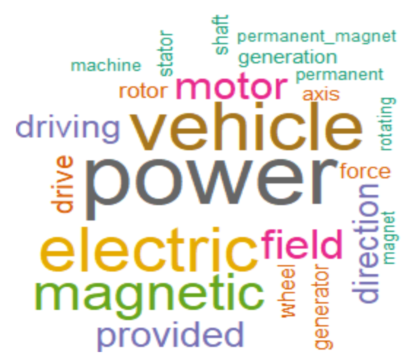
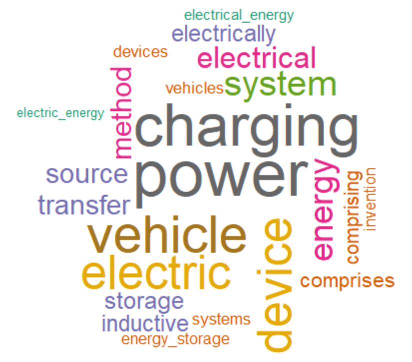
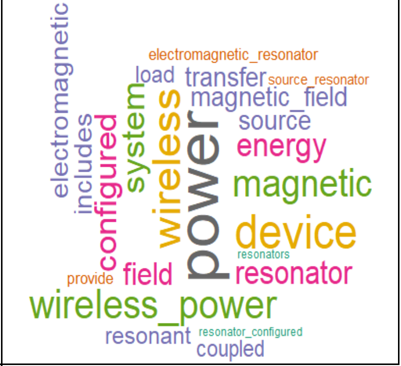
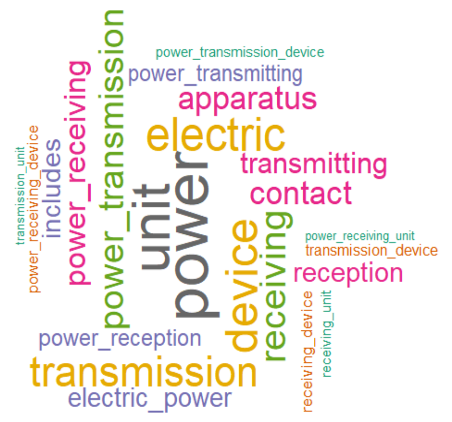
Topics 14 (power feeding), 15 (control unit), and 16 (charging systems) used the labels created using the labeltopics() function. Similarly, topics 17 and 18 focus on battery_management and wireless_power_transfer areas. Topic 19 was labeled as permanent_magnet, which did not make sense. Therefore, it was changed into "electric_motor" as the terms address information regarding the electric motor. Topic 20 was changed from electromagnetic_resonator to "mangetic_resonance" because magnetic_field, wireless_power, transfer, resonator, load, and coupled explain magnetic_resonance. Topic 21 (electromagnetic_resonators) used the labels created using the labeltopics function. According to Kristensen et al. (2020), electromagnetic resonators come in various forms and sizes, from microwave resonators to semiconductor lasers.

For topic 22, it was previously labeled as electric_vehicle but changed to "motor_controller" as the terms such as braking, mode, speed, controller, and cooling refer to the motor controller instead of the whole EV. Finally, topic 23 addresses areas about "power_transmission."

The top terms for each topic can be visualized in the form of a word cloud. Table 20 shows the word cloud for each topic. A word cloud is a visualization that shows the importance level of the keywords represented in the corpus. A word in the word cloud is more important in the corpus when bigger and bolder. For example, for topic 5, the importance of battery, power unit, and charging does align with the topic label of "charging." However, despite the usefulness of word cloud in quickly understanding the topic, it does not show any relationships between them. Therefore, in the next section, the dissertation examines the topic rankings and discusses the change in topics over time.

Table 20
Word cloud for each topic

Topic 1, magnetic_induction	Topic 2, electric_vehicle	Topic 3, communication
		
Topic 4, near_field	Topic 5, charging	Topic 6, batteries
		
Topic 7, magnetic_resonance	Topic 8, connector	Topic 9, microwave_based
		
Topic 10, battery_module	Topic 11, power_conversion	Topic 12, electrodes
		

Topic 13, far_field	Topic 14, power feeding	Topic 15, control unit
		
Topic 16, charging station	Topic 17, battery management	Topic 18, wireless_power_transfer
		
Topic 19, electric_motor	Topic 20, energy storage	Topic 21, electromagnetic_resonators
		
Topic 22, motor_controller	Topic 23, power transmission	
		

5.3.2.3 Topic Ranking

Before examining the topic change over time, the dissertation ranks the topics by coherence and prevalence scores. Topic prevalence is widely used to measure and rank the topics. In all types of topic modeling, the proportion of words attributable to each topic for each document is estimated (Roberts et al., 2014). The prevalence measures how much a document (a patent) is associated with a topic (Roberts et al., 2019) and the probability of topic distribution in the corpus (Jones, 2021). Equation 9 is used to calculate the prevalence value of the patents. The dissertation calculated the prevalence score, theta (Θ), for each topic using the FitLDAModel() function.

$$Prevalence \ = \frac{colSums(\theta)}{\sum \theta} \times 100 \qquad \text{Equation 8}$$

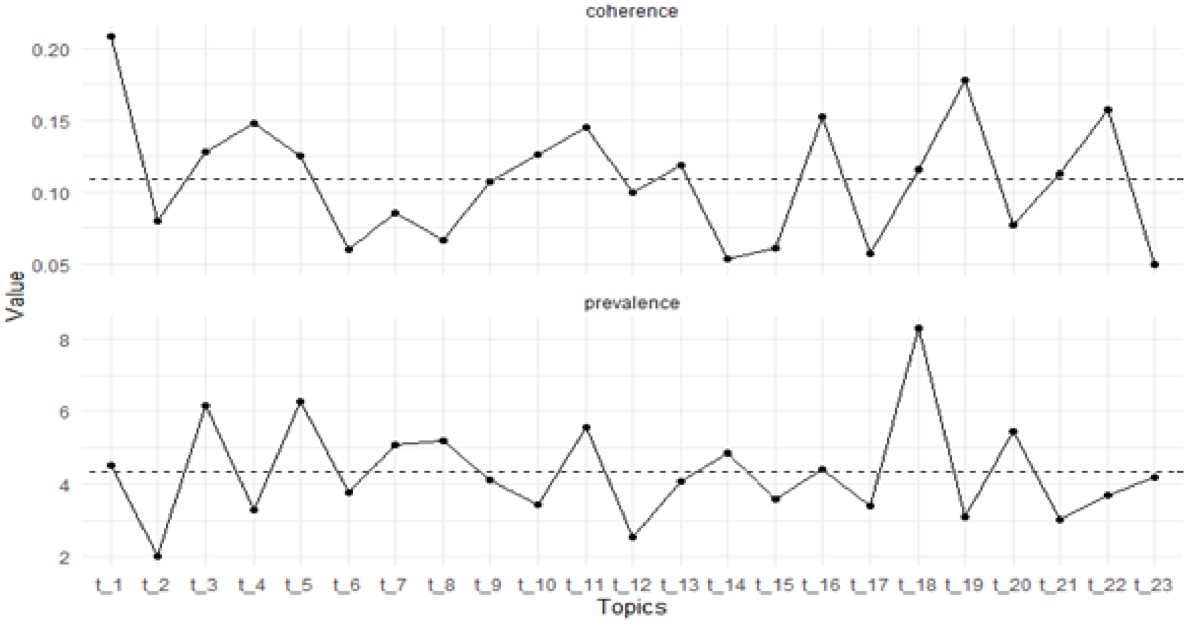
Where colSums refers to the colsums() function in R that computes the sums of matrix or array's columns.

For this dissertation, probabilistic coherence is also considered because probabilistic coherence is a measurement to show how associated words are in the topic (Jones, 2021). Newman et al. (2010) defined coherence as the average semantic relatedness between topic words and provided the best correlation. In addition, Stevens et al. (2012) defined coherence value as a score that measures the degree of semantic similarity between high-scoring words in the topic. Coherence value can help differentiate semantically interpretable topics from artifacts of statistical inference (Stevens et al., 2012). Stevens et al. (2012) stated that coherence is a sum of pairwise distribution similarity scores over the set of topic words, V, computed in Equation 8. The dissertation uses the FitLDAModel() function to calculate the coherence.

$$coherence(V) = \sum_{(v_i, v_j) \in V} score(v_i, v_j, \epsilon) \qquad \text{Equation 9}$$

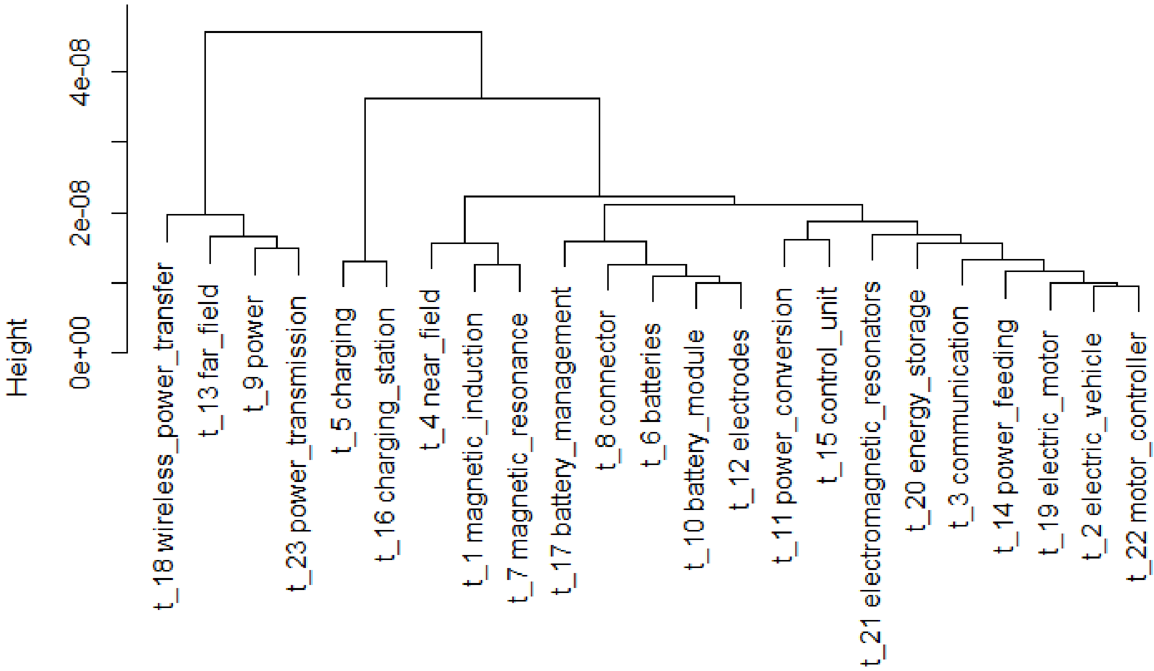
The dissertation examines the coherence and prevalence scores for each topic. Figure 34 compares the coherences and prevalence scores of all topics. The dotted line in each graph shows the average scores among the topics. From the figure, topic 1 has the highest quality, meaning the words in this topic are associated with each other and have a prevalence score higher than the average. On the other hand, topic 19 has the second-highest coherence value, but it is much lower than the average prevalence score. Six topics have coherence and prevalence scores above average. Therefore, the dissertation confirms that topics 1 (magnetic_inductive), 3 (communication), 5 (charging), 11 (power_conversion), 16 (charging_station) and 18 (wireless_power_transfer) are the top topics of EV wireless charging patents.

Figure 34
Coherence and prevalence scores for each topic



The dissertation created a dendrogram to examine how the topics relate. A cluster dendrogram (Figure 35) is created based on Hellinger distance, a distance between 2 probability vectors, and can be calculated using CalcHellingerDist() function from the texmineR package (Christian, 2020). The dendrogram suggests similarities between topics 2 (electric_vehicle) and 22 (motor controller). In addition, topic 1 (magnetic_inductive) and 7 (magnetic_resonance) show similarities, as well as topics 10 (battery_module) and 12 (electrodes).

Figure 35
Cluster dendrogram of the topics



5.3.2.4 Topic Trend Analysis of EV Wireless Charging Patents

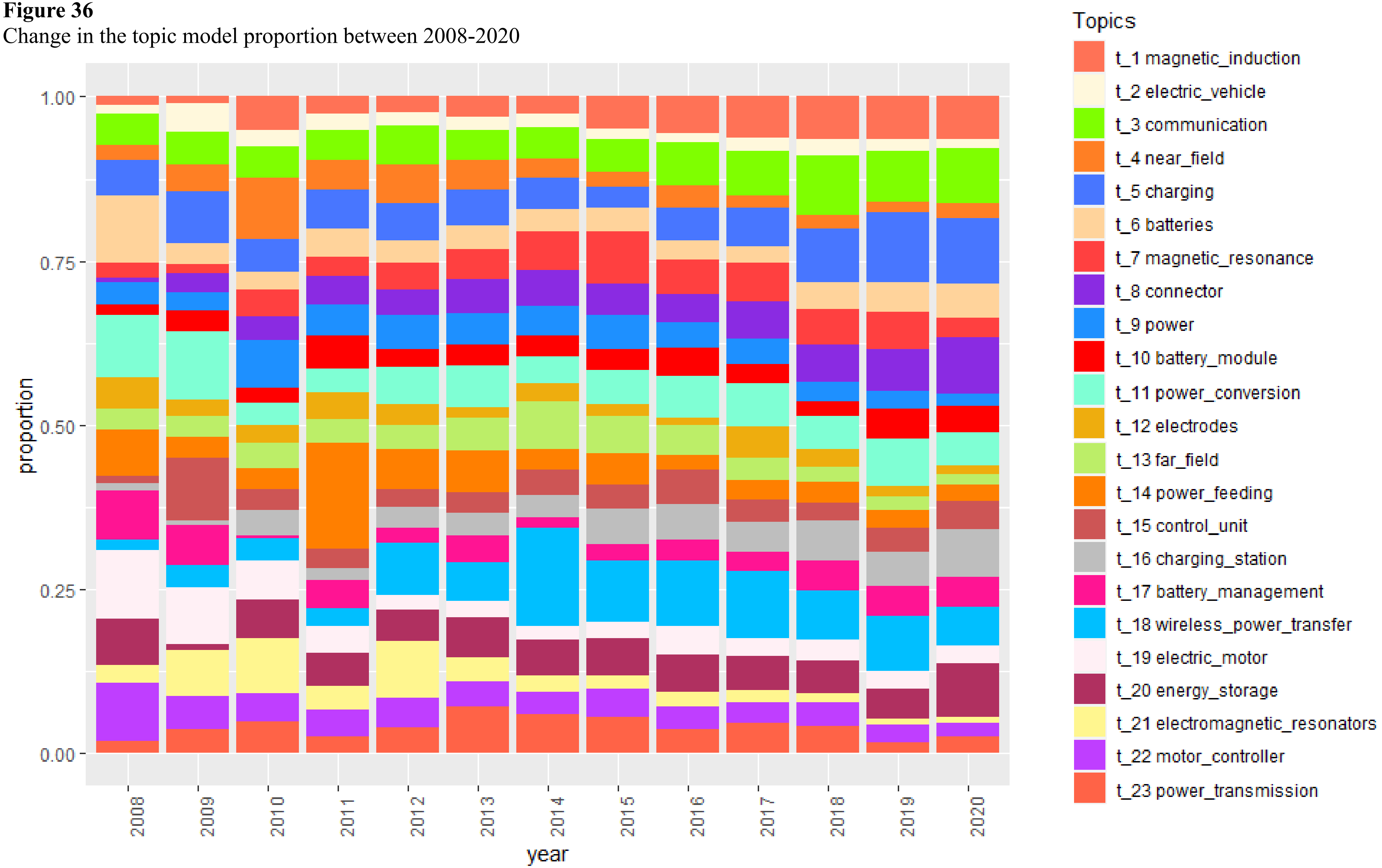
Figure 36 shows the change in the topic proportion between 2008-and 2020. The topics can be factored into four groups. The first group is where the patents related to these topics showed a continuous increase over the years. Topics 1 (magnetic_induction), 3 (communications), 5 (charging), 8 (connector), 16 (charging stations), and 18 (wireless_power_transfer) showed continuous increase between 2008 and 2020.

The second group is where the patents related to these topics showed a continuous decrease over the years. Topics 2 (electric_vehicle), 4 (near_field), 6 (batteries), 19 (electric_motor), 21 (electromagnetic_resonator) and 22 (motor_controller) showed continuous decrease between 2008 and 2020. The third group is where the patents related to these topics first showed an increasing trend, then decreased proportion. Topics 7 (magnetic_resonance), 9 (power), 11 (power_conversion), 13 (far_field), 14 (power_feeding), 15 (control_unit), 17 (battery_management), and 23 (power_transmission) belong to the third group.

Lastly, the final group is where patents related to these topics did not show major changes over the years. Topics 10 (battery_module), 12 (electrodes) and 20 (energy_storage) belong to the last group. The dissertation can conclude that many patents in 2020 were related to magnetic induction, communications, charging, connector, and energy storage. In terms of near-field and far-field wireless technology, there seems to be a minimal difference between the two technologies in 2020. In addition, when comparing magnetic induction and magnetic resonance, it is clear that magnetic induction is currently more patented than magnetic resonance from 2016. In addition, topics 9 (power) and 23 (power_transmission), which were related to far-field according to the dendrogram, are not popular topics in 2020, according to Figure 36.

Figure 36

Change in the topic model proportion between 2008-2020



5.4 Local Outlier Factoring and Principal Component Analysis

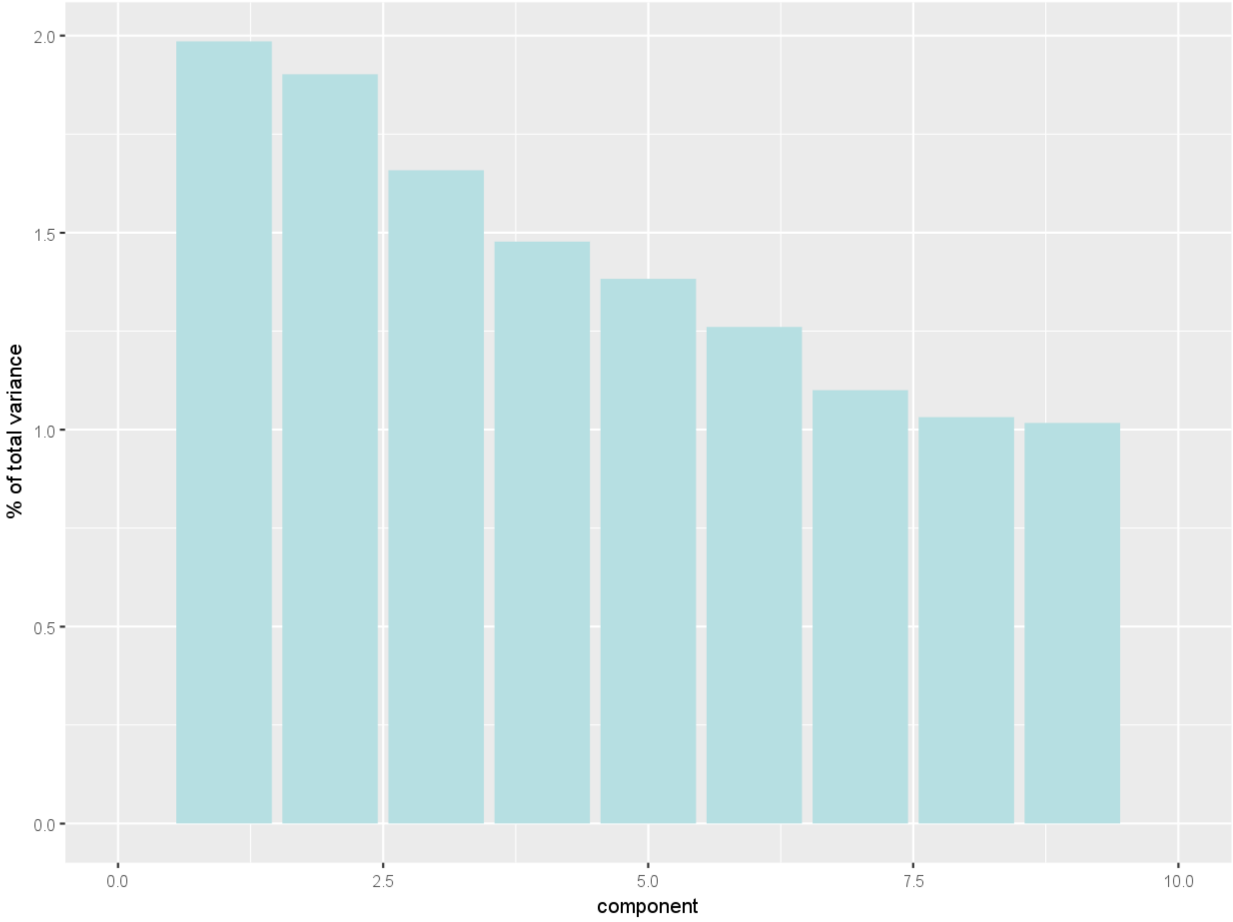
5.4.1 Principal Component Analysis

Müller et al. (2006) stated that applying the PCA can enrich a dataset and make data more explicit. Furthermore, the authors stated that visualizing data by principal component space instead of the original data mapping space can present prominent trends in the data. The dissertation used the two functions (recipes and prep) from the "recipes" package in R to conduct the PCA.

The recipe function is needed to describe what steps should be applied to a dataset to get the data ready for analysis. In other words, the recipe function is the data preprocessing stage before conducting data analysis. The recipe functions require an ingredient (a dataset) for input and recipes (different pre-processing steps). The ingredient is the document-term matrix created during the topic modeling analysis in the previous section but filtered to include patents between 2008 and 2017. Three recipes are used. First, the role of patent publication number and assignees are updated as "identifiers" because these variables should be kept for convenience but are not used for analysis results. Second, numeric variables are normalized to be used in the PCA. Finally, the step_pca() function is used to conduct the PCA. The recipe() function does not provide an output since it only defines what steps should be implemented. The prep() function is where the recipes defined are implemented and run.

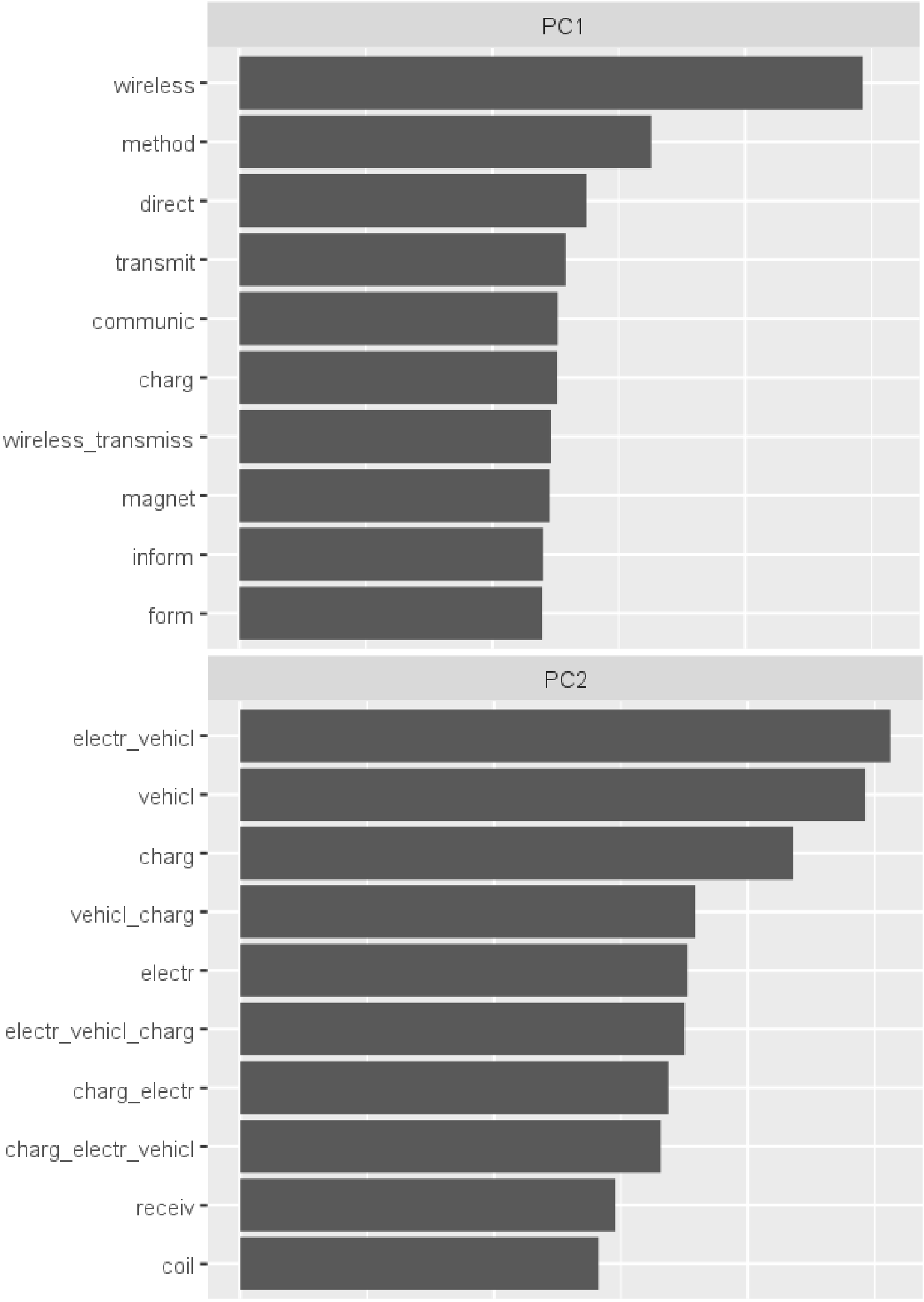
After conducting the PCA, the next step is to examine the principal components (PC). One way to compare the PCs is to examine the percent of the variance, the ratio of variance accounted by each component, and all variables' total variance. It is widely understood that the larger the variance of a component, the larger the dispersion of the component. Moreover, the larger the dispersion of a component, the more informative that component has. Figure 37 shows the percentage of variance accounted for the first ten components. The figure shows that PC1 and PC2 account for the largest variance, despite each component being lower than 2% of the whole variance.

Figure 37
Percentage of variance accounted for each component



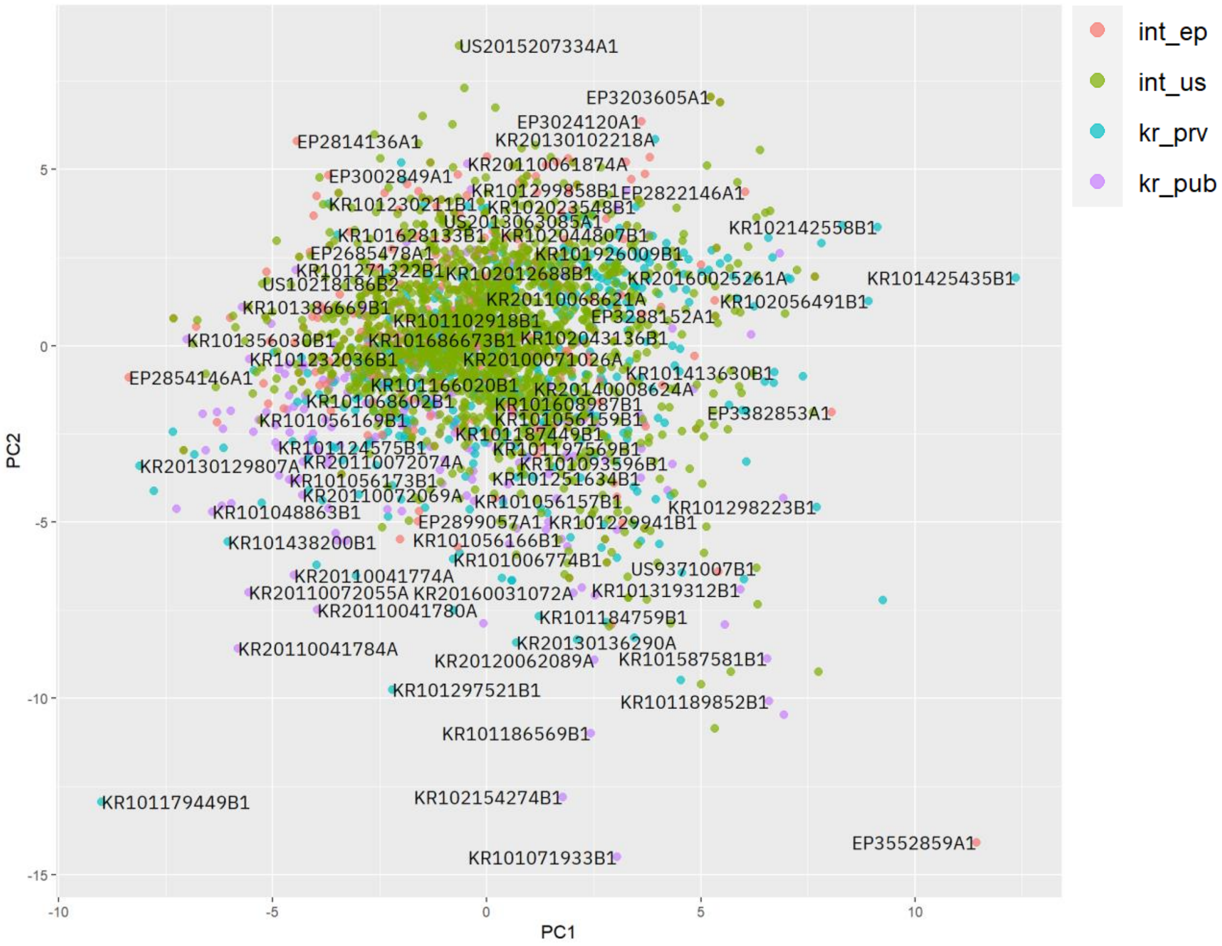
The dissertation examined PC1 and PC2 closely to understand what each component is referring to. Therefore, the top 10 terms for each component are shown in Figure 38. By examining the top 10 terms, PC1 is mostly about wireless transmission, while PC2 is about electric vehicles and charging.

Figure 38
Top 10 terms in PC1 and PC2 in terms of the absolute value of the contribution



A PCA plot was created using the best two principal components (PC1 and PC2) to visualize the document-term matrix of the patent abstracts. Figure 39 shows the PC1 and PC2 biplot labeled by the assignee types. In the next section, the dissertation uses this PCA plot to examine the outlier scores for each patent point by conducting the LOF.

Figure 39
PC1 and PC2 biplot



5.4.2 Local Outlier Factoring

5.4.2.1 K-Selection, the number of nearest neighbors

The first step before conducting the LOF is to determine the number of nearest neighbors, K. As stated in Chapter 3, the dissertation uses two methods, the rule of thumb and the RMSE fit.

The dissertation first divides the data set into training and testing sets using the rule of thumb “80-20” division to find the number of K using the rule of thumb and the RMSE. The total number of variables used for the PCA and LOF analysis is 2,883. Therefore, the training set is 2,306, while the testing set is 577. Using the rule of thumb, the square root of 2,306 is 48, but since it needs to be an odd number, it might be 47 or 49.

The dissertation uses the knn.reg() function from the “*FNN*” package in R to conduct the RMSE of both training and testing sets. The dissertation found the best fit by finding the K that coincides with the minimum test sample RMSE. Dalpiaz (2020) states that K values smaller than the “best fit” K are “overfitting,” and K values larger than the best-fit K are “underfitting.” The dissertation examines the RMSE fit for K between 41 and 75 (Table 21). From the analysis, K as 57 shows the best fit.

Table 21
Best RMSE fit from K 41 to 75

K	Train RMSE	Test RMSE	Fit?
41	2.36	2.23	Over
43	2.36	2.23	Over
45	2.36	2.23	Over
47	2.36	2.23	Over
49	2.37	2.24	Over
51	2.37	2.24	Over
53	2.37	2.24	Over
55	2.37	2.23	Over
57	2.36	2.23	Best
59	2.36	2.23	Under
61	2.37	2.23	Under
63	2.37	2.24	Under
65	2.37	2.24	Under
67	2.37	2.24	Under
69	2.37	2.24	Under
71	2.37	2.24	Under
73	2.37	2.24	Under
75	2.37	2.23	Under

5.4.2.2 Computing Outlier Scores

The dissertation used the lof() function in the "*Rlof*" package to compute the outlier scores.

Table 22 shows the top five rare patents found according to the outlier scores.

Patent No.	Rarity
114	3.7880042
1005	2.5923444
1087	2.6872159
1223	2.9488739
2537	2.5923444

Table 22
Top 5 Rare Patents and its Outlier Scores

5.5 Patent Mapping

Before creating the patent map, the dissertation normalized the variables (the number of forward citations, the number of claims, and the outlier scores) to prevent any potential issues due to the difference in patent age and patent offices. Table 23 shows the descriptive summary of the normalized data used to create the patent map.

Table 23
Descriptive summary of the normalized data used for patent mapping

	No. Forward Citations	No. of Claims	Outlier Scores
Min	0	0	0
1st Quartile	0	0.044	0.028
Median	0.002	0.077	0.050
Mean	0.022	0.080	0.069
3rd Quartile	0.012	0.086	0.103

Max	1.00	1.00	1.00

The dissertation uses the ggplot() function from the "*ggplot2*" package. Figure 40 shows the patent map for the EV wireless charging patents from the EPO, KIPO, and the USPTO. The classification boundary is created using the mean value for each axis. The majority of the patents are located on the left side of the patent map, indicating that most patents are not valuable and imitable. Furthermore, all patents located in the top right region, which resemble valuable, inimitable and substitutable patents, are from the USPTO database.

The most important region is located at the bottom right. Using the mean value of the outlier scores as the threshold level of the rarity, the patent map determined the VRIN patents. Figure 41 shows the zoom-in version of the VRIN patents for the EV wireless charging patents from the EPO, KIPO, and the USPTO. The dissertation filtered out patents filed in KIPO to examine Korean patents and their VRIN attributes.

Figure 42 shows the patent map for the EV wireless charging patents filed by Korean public organizations and private organizations and patents with VRIN attributes.

Figure 40

VRIN-Identification patent map for the EV wireless charging patents from the EPO, KIPO, and the USPTO

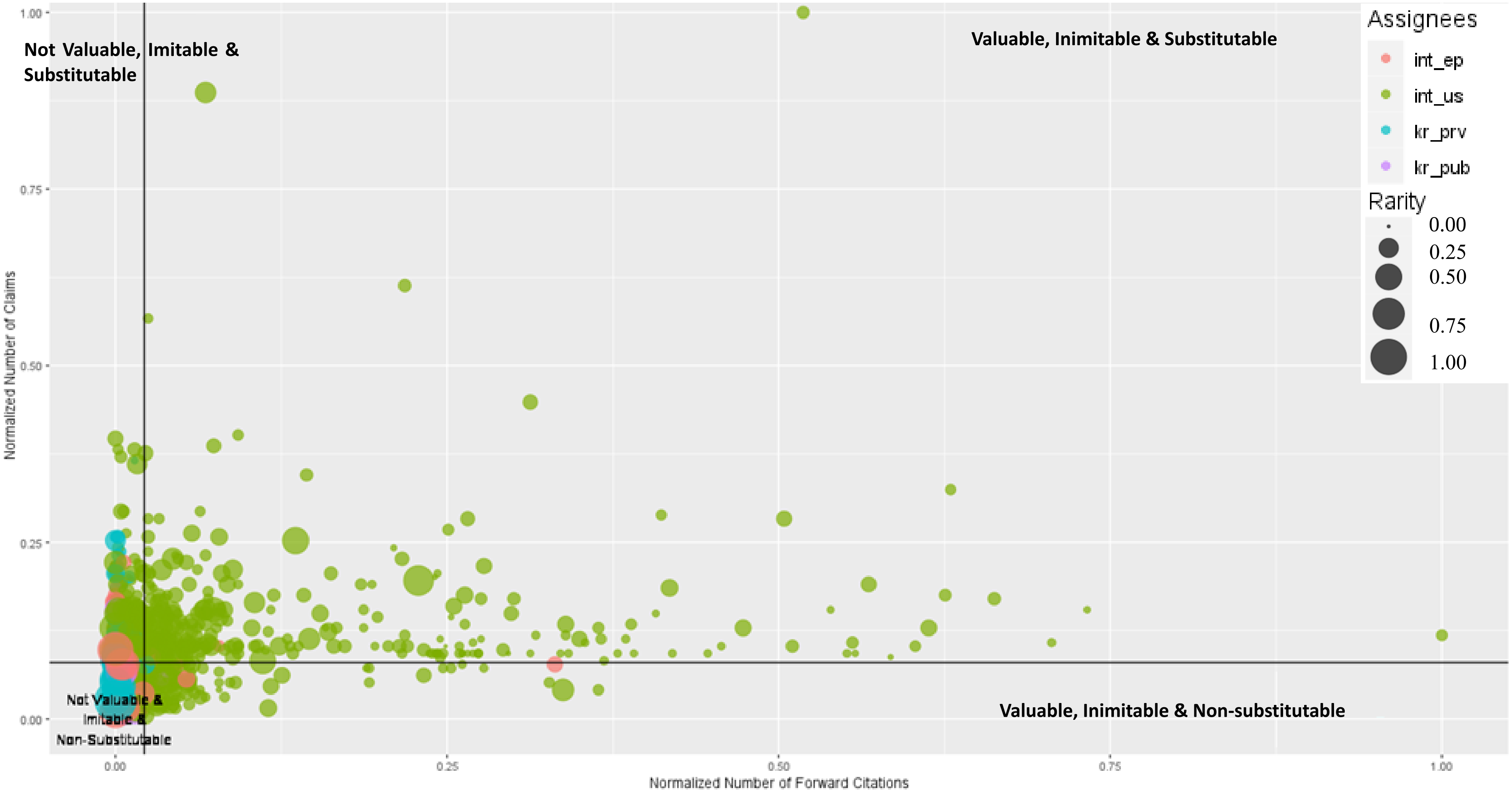


Figure 41

Zoom-in version of the VRIN patents for the EV wireless charging patents from the EPO, KIPO, and the USPTO

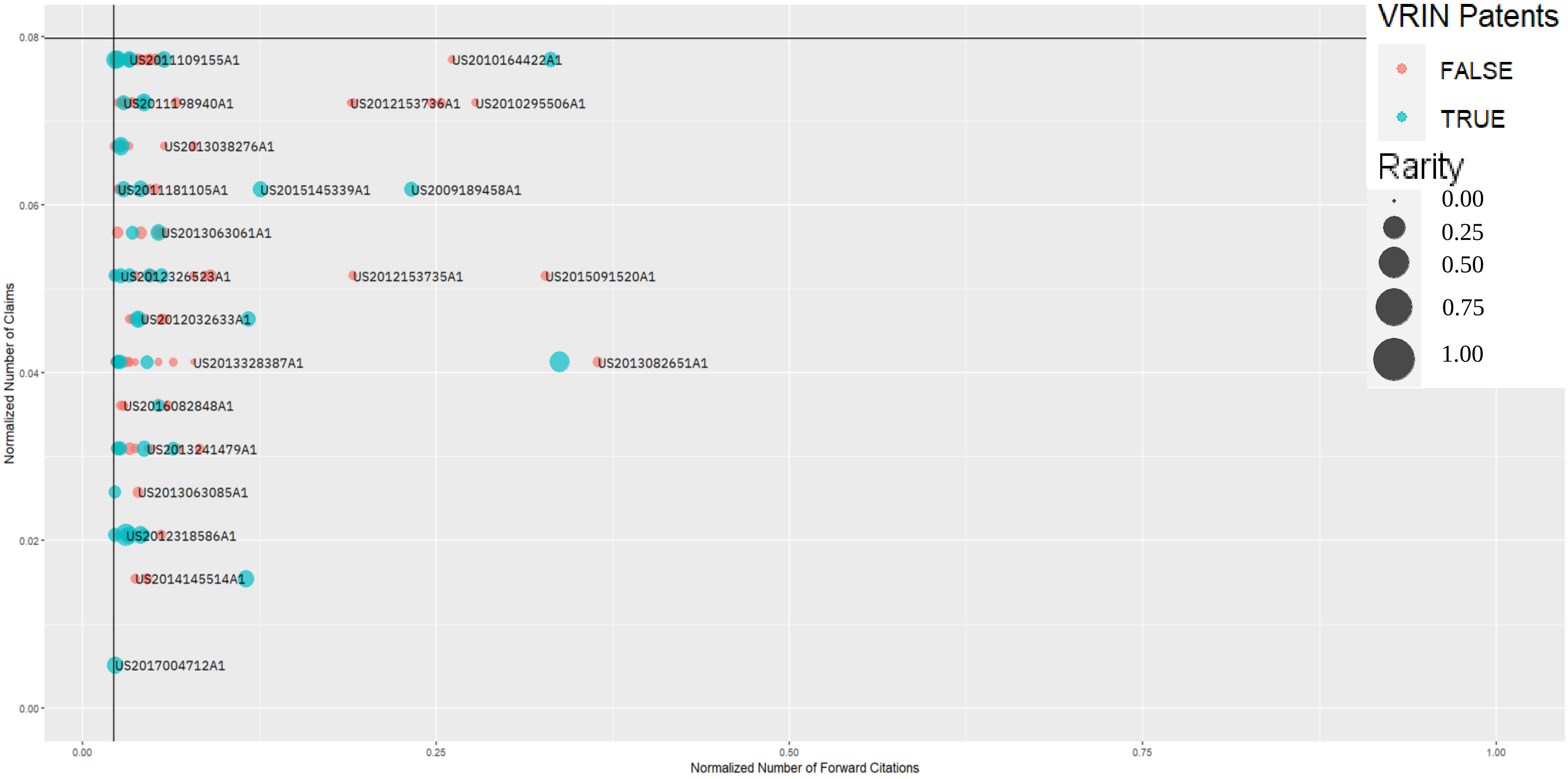
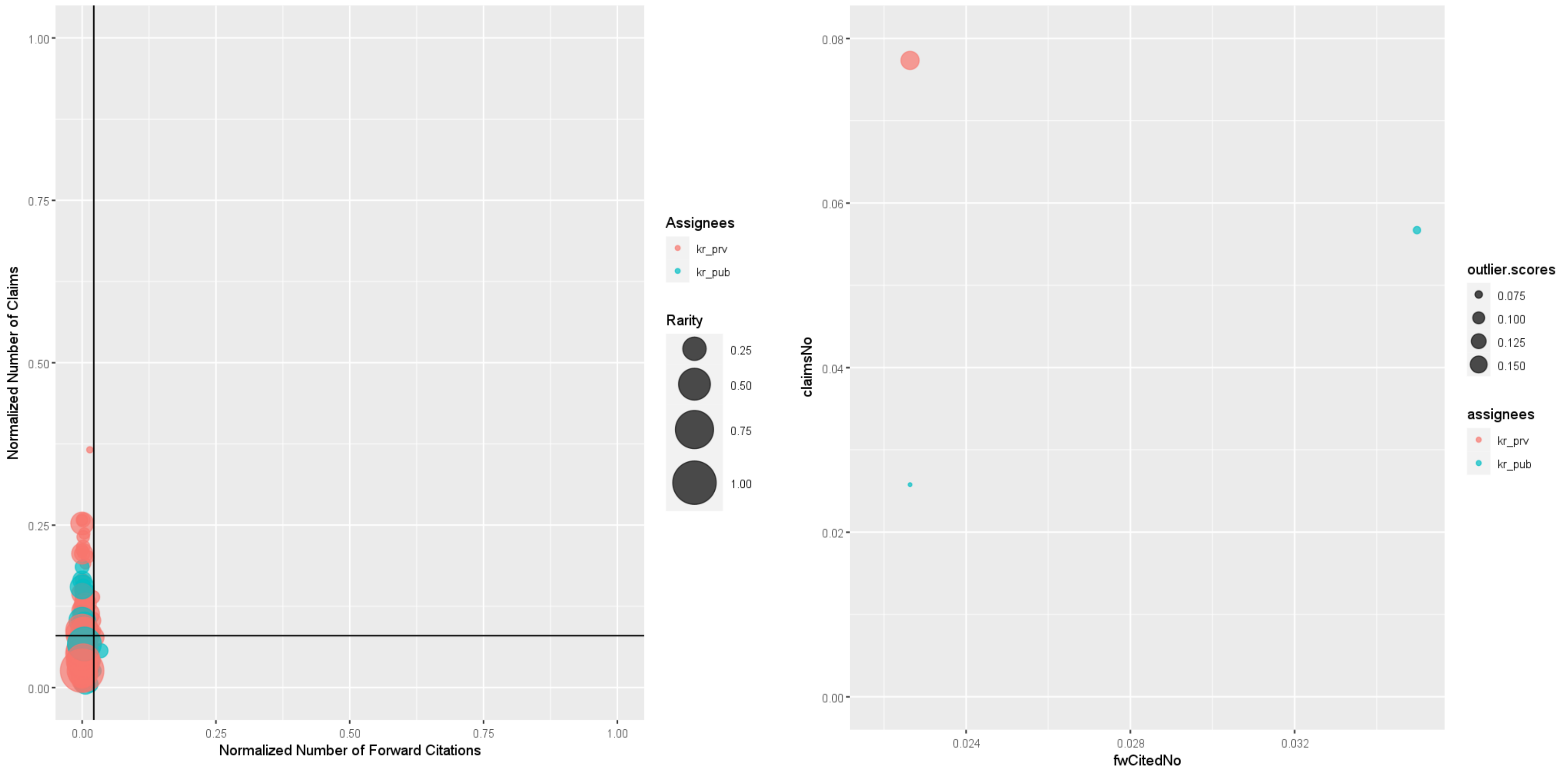


Figure 42

VRIN Patent Map for Korean Patent

A B



Note. A) A patent map for the EV wireless charging patents filed by the Korean public organizations and private organizations

B) VRIN patents published in KIPO located in the bottom right region of Figure 44A

The majority of the patents are located on the left side of the patent map, which is very similar to the patent map of the whole data set. Interestingly, four patents are found in the bottom right (valuable, inimitable, and non-substitutable) region. After examining their rarity level (outlier scores), three patents have VRIN attributes, of which the public organizations own two of them. Table 24 shows the VRIN attribute levels of the VRIN Korean patents. Interestingly, the patent owned by the private organization had a higher rarity level and the highest number of claims (remember that the dissertation assumed a higher number of claims would decrease the non-substitutable level) compared to the two patents owned by the public organization.

Table 24
Comparing the VRIN levels of the VRIN Korean patents

Patents	No. of Forward Citations	Outlier Scores	No. of Claims
Private Organization	0.022633745	0.165091352	0.077319588
Public Organization 1	0.034979424	0.075117468	0.056701031
Public Organization 2	0.022633745	0.069088103	0.025773196

5.5.1 Identified VRIN EV Wireless Charging Patents

Instead of comparing the VRIN attributes of all EV wireless charging patents, the dissertation examined just the VRIN patents because these patents can provide competitive advantages to both the firm and the country, and also, these are the types of patents that governments must identify to ensure better technology transfer performance and higher international competitiveness in the EV industry. The following 46 patents have VRIN attributes (Table 26). There are three KIPO patents, of which two are owned by public organizations, three EPO patents, and forty patents from the USPTO. In terms of publication year, there are two patents published in 2008, one patent in 2009, four patents in 2010, eight patents in 2011, six patents in 2012, twelve patents in 2013, seven patents in 2014, five patents in 2015, and one patent in 2017. Interestingly, no patents published in 2016 are VRIN patents.

Furthermore, no Korean patents are found in the top 20 in terms of value and inimitability. Nine of the top ten rare patents are filed in the USPTO, and surprisingly, a patent owned by a Korean private organization is ranked fourth in rarity. Similarly, one patent owned by the Korean public organization is ranked in the top ten in terms of non-substitutability. Table 25 compares the average VRIN attributes of the VRIN EV wireless charging patents found on the patent map. The dissertation result supports that Korean public organizations' VRIN EV wireless charging patents have lower average VRIN attributes than VRIN EV wireless charging patents in the USPTO. Furthermore, it is not easy to prove that VRIN EV wireless charging patents owned by Korean private organizations are superior to the VRIN EV wireless charging patents owned by Korean public organizations in terms of average VRIN attributes.

Table 25
Comparing average VRIN attribute levels of VRIN EV wireless charging patents

		VRIN Patents	Average VRIN Attributes			
			Value (V)	Rarity (R)	Inimitability (I)	Non-substitutability (N)
KIPO	Public	2 / 233	0.028807	0.072103	0.028807	0.041237
	Private	1 / 511	0.022634	0.165091	0.022634	0.07732
	Total	3 / 744	0.026749	0.103099	0.026749	0.053265
USTPO		40 / 1645	0.054218	0.114825	0.054218	0.047165
EPO		3 / 494	0.144033	0.102458	0.144033	0.070447
Total		46 / 2883	0.058284	0.113254	0.058284	0.049081

Note. The higher average number of forward citations = Higher value and Inimitable attributes.

Higher average outlier scores = Higher Rarity attribute

The higher average number of claims = Lower Non-substitutability attributes

Table 26
VRIN patents

Patent number	Title	Assignees	No. of Forward Citations(V, I)	Outlier Scores (R)	No. of Claims (N)
KR20080040271A	3 phase amorphous inductive power transfer system of electric railway vehicle	kr_pub	0.022634	0.069088	0.025773
KR101045585B1	wireless power transfer device for reducing electromagnetic wave leakage	kr_pub	0.034979	0.075117	0.056701
KR20130102218A	wireless power receiving device with multi coil and wireless power receiving method	kr_prv	0.022634	0.165091	0.07732
EP2199143A1	system and method for electric vehicle charging and billing using a wireless vehicle communication service	int_ep	0.047325	0.071444	0.07732
EP2346136A1	apparatus for generating an alternating magnetic field and apparatus for providing an effective power from an alternating magnetic field	int_ep	0.331276	0.117486	0.07732
EP2656718A1	a ground care apparatus and a charging station apparatus therefor	int_ep	0.053498	0.118444	0.056701
US2011291615A1	wireless charging system for vehicles	int_us	0.063786	0.084878	0.030928
US2011049978A1	self-resonant coil, non-contact electric power transfer device and vehicle	int_us	0.039095	0.072554	0.046392
US2009189458A1	vehicle power supply apparatus and vehicle window member	int_us	0.23251	0.094057	0.061856
US2011012562A1	low temperature charging of li-ion cells	int_us	0.041152	0.147919	0.020619
US2010231173A1	bi-directional inverter-charger	int_us	0.045267	0.089883	0.041237
US2011210746A1	power supply device and method for detecting non-contact state of load connected to power supply device	int_us	0.039095	0.137403	0.046392
US2011204715A1	power supply control device	int_us	0.024691	0.093038	0.030928
US2010097830A1	induction power system	int_us	0.030864	0.080901	0.020619
US2010219706A1	power transmission apparatus	int_us	0.028807	0.119693	0.072165

US2008129246A1	non-contact type power feeder system for mobile object and protecting apparatus thereof	int_us	0.117284	0.142954	0.046392
US2011253495A1	producing electromagnetic fields for transferring electric energy to a vehicle	int_us	0.04321	0.186118	0.072165
US2012306439A1	vehicle charging apparatus	int_us	0.049383	0.071165	0.051546
US2012176090A1	bi-directional inverter-charger	int_us	0.024691	0.089883	0.041237
US2012326499A1	power transmission system and power supply device for vehicles	int_us	0.04321	0.126736	0.030928
US2012169129A1	energy storage device	int_us	0.032922	0.120825	0.07732
US2012217112A1	transferring electric energy to a vehicle, using a system which comprises consecutive segments for energy transfer	int_us	0.026749	0.147324	0.06701
US2012173066A1	electric motor drive system for an electric vehicle	int_us	0.041152	0.128735	0.061856
US2013175987A1	charging apparatus for electric vehicle	int_us	0.026749	0.103472	0.051546
US2013038135A1	non contact-power receiving/transmitting device and manufacturing method therefor	int_us	0.032922	0.094093	0.07732
US2013026850A1	noncontact power feeding apparatus and noncontact power feeding method	int_us	0.047325	0.086971	0.051546
US2013057208A1	power reception equipment for resonance-type non-contact power supply system	int_us	0.026749	0.080522	0.030928
US2013314039A1	charging device for an electric energy storage device in a motor vehicle	int_us	0.04321	0.080936	0.020619
US2013088194A1	overhead power transfer system	int_us	0.032922	0.07919	0.051546
US8384344B1	system and method for charging a battery within a vehicle	int_us	0.024691	0.143456	0.07732
US2013093254A1	wireless power feeder and wireless power transmission system	int_us	0.026749	0.088844	0.041237
US2013335018A1	coil unit, power transmission device, external power feeding apparatus, and vehicle charging system	int_us	0.028807	0.112804	0.061856

US2013088177A1	device and method for power-saving driving of device having same load pattern	int_us	0.022634	0.069098	0.051546
US2014320078A1	vehicle and power transfer system	int_us	0.026749	0.087861	0.06701
US2014092243A1	non-contact power receiving apparatus, non-contact power transmitting apparatus, and non-contact power transmitting and receiving system	int_us	0.032922	0.079775	0.07732
US2014097671A1	non-contact power receiving apparatus, non-contact power transmitting apparatus, and non-contact power transmitting/receiving system	int_us	0.047325	0.074197	0.051546
US2014132208A1	system and method to align a source resonator and a capture resonator for wireless electrical power transfer	int_us	0.057613	0.137041	0.07732
US2014145516A1	wireless power transmission method	int_us	0.115226	0.138432	0.015464
US2014035520A1	wireless charging system	int_us	0.024691	0.085573	0.041237
US2014354291A1	battery monitoring system, host controller, and battery monitoring device	int_us	0.030864	0.27311	0.020619
US2015061580A1	electric power transmission system	int_us	0.032922	0.150754	0.020619
US2015028688A1	wireless power transfer system, power transmission device, power receiving device, and control method of wireless power transfer system	int_us	0.337449	0.238474	0.041237
US2015200550A1	wireless power-supplying system	int_us	0.022634	0.08097	0.020619
US2015145339A1	power feeding coil unit and wireless power transmission device	int_us	0.125514	0.131696	0.061856
US2015137612A1	antenna coil	int_us	0.055556	0.105507	0.051546
US2017004712A1	regional electric vehicle sharing and management system and method	int_us	0.022634	0.136176	0.005155

5.6 Validation Process

The dissertation was approved and exempted by SUNY Korea Institutional Review Board, and the approved letter is shown in Appendix A. The questionnaire was created through two online websites (Google forms[30] and Qualtrics[31]), and 48 responses were collected. After review, 45 responses (16 Korean, 28 English) were used to validate the VRIN patent map, as the three responses had more than half unanswered questions. Table 27 shows the breakdown of the experts affiliated with institutions and fields of expertise. Twenty of the experts are affiliated with TTOs and TLOs, and around four experts are working in the field related to EVs. In addition, fourteen experts are either patent attorneys, patent analysts, or consultants related to technology transfer. Also, one expert is the CEO of the European members association, comprising knowledge transfer professionals.

Table 27
Experts Affiliated Institutions and Field of Expertise

TTOs and TLOs	Firms involved in Electric Vehicle technology	Research institutes involved in Electric Vehicle technology	University faculty involved in intellectual property	Others[32]
20	1	3	7	14

When asked about their experience working with patents, thirty-eight experts responded that they have worked with patents, while six experts have not used patent analysis because they think patent analysis results are difficult to understand and faced difficulty in collecting and analyzing patent information. According to the experts who have conducted patent analysis,

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[30] https://www.google.com/forms/about/

[31] https://www.qualtrics.com/

[32] Includes patent attorneys, patent analysts, patent examiners, law firm, IP management firm. and CEOs

patent abstracts, patent claims, assignee information and the number of forward and backward citations are commonly used variables, while the number of claims, inventor information, legal status, patent specifications and images are also used, but not as often.

Table 28 shows some examples of commonly used patent analysis methodologies and the experts opinions on the drawbacks of the methods. For example, one of the most used methods was commercial software such as InnovationQ and Patsnap. While two experts found no drawbacks to using commercial software, nine experts believe looking at claims of individual patents can provide more information but tends to be more tedious and slow. Three experts have used text mining techniques with patent information, but twenty-three experts had difficulties conducting a patent analysis due to 1) lack of patent information, 2) time-consuming, and 3) difficulty in carrying out and understanding the results. Also, thirty-four experts have used patent mapping.

Table 28
Commonly Used Patent Analysis Methods and the Drawbacks According to the Experts

Patent Analysis Methods	Drawbacks
Manual search in public and paid databases	“Slow and time-consuming”
Claim Charts and Patent Landscapes	“Information of published patents/applications have an 18-month lag time” “Can be tedious and slow”
Innography and grouping/evaluation of patent families	"No patent analysis answers the question about product/market fit, which ultimately dictates/determines value”
Commercial software e.g. InnovationQ, Patsnap	“Graphic approaches give a nice high-level picture but do not provide detailed competitive analysis. Looking at the claims in individual patents is more specific but tedious and slow”
Spreadsheets	“Unwieldy when analyzing a large number of cases”
Text analysis and some machine learning algorithms	“Lack of more patent information”
Comparing one’s inventive elements to prior art	“Takes a while to conduct this analysis, partly due to how patents are written and how the prosecution is conducted”
Patent mapping	“Requires additional method for claims analysis”

Furthermore, the thirty-eight experts believe that patents have different values, rarity, inimitable and non-substitutable levels. Table 29 breaks down the experts view on the dissertation measurement of value, rarity, inimitable and non-substitutable levels. Unfortunately, six experts did not respond to the questions regarding the VRIN measurement validation. Twenty-three experts agreed that the number of forward citations is a valid measurement for the value and inimitability of patents. On the other hand, twenty-one experts disagreed on the measurement of a patent rarity as the outlier scores of the patent abstract, and only six experts agreed that the number of claims is a valid measurement for the non-substitutability of patents.

Table 29
Experts' view of the measurement of VRIN Attributes of the Dissertation

	Can patents have different values, rarity, inimitable and non-substitutable levels?	Number of Forward Citations as Value and Inimitability	Extremely high outliers in patent abstracts as Rarity	Number of Claims as Non-substitutability
Yes	38	23	18	6
No	1	16	21	33
No response	6	6	6	6

The outcome of the validation for the rarity and the non-substitutability of patents can be due to several reasons. First, the experts might not have been familiar with outlier detection as it is not widely used in patent analysis, and the questionnaire could not go in-depth in explaining the process of identifying the outlier scores for the rarity. The lack of explanation might have caused the experts to disagree with the measurement of rarity.

Second, the number of claims was commonly used in patent analysis, and past studies (Reitzig, 2003; Fischer and Leidinger, 2014; Og et al., 2020) showed a positive correlation between the number of claims and the patent's legal sustainability and values. Therefore, there is a conflict between the dissertation definition of patent rarity and past studies' definition of patent values. Furthermore, the average number of claims in patent applications varies significantly across patent offices, as patents filed at the USPTO had 17.8 claims, patents filed at the EPO had 14.2 claims, and patents filed at the KIPO had 11.1 claims (Five IP Offices, 2019). Therefore, another measurement could have been considered. For example, Okada et al. (2016) suggested that the increase in the number of words in the first independent claim can be a proxy for reducing the patent scope. Therefore, the breadth of a patent claim, in terms of the inverse of the first independent claim length, could be a good alternative for measuring non-substitutability.

Table 30 shows the experts' view on the usefulness of the VRIN patent map, the relationship between patents with a competitive advantage, and the likelihood of being transferred and generating licensing revenue. First, thirty-one experts think the VRIN Patent Map can provide meaningful information by identifying patents with a competitive advantage. Second, the experts also think that patents with a competitive advantage will more likely be transferred, thus showing promise for generating licensing revenue.

Table 30
Experts view the usefulness of the VRIN Patent Map and the objective of the Dissertation

	Do you think a patent map such as the VRIN Patent Map can provide meaningful information and be used in identifying patents with a competitive advantage	Do you think patents with a more competitive advantage can have a higher likelihood of being transferred and show promise for generating licensing revenue
Yes	31	32
No	9	8
No response	5	5

5.7 Discussion

This chapter presented the research outcome of both topic modeling to identify emerging technology/trends and the VRIN identifying patent map to provide a method to identify patents with competitive advantages and assess technology transfer as a performance-oriented variable. The dissertation successfully collected patent information, conducted two unique research techniques, and validated the results through an online questionnaire to experts in technology transfer and patents. Table 31 shows whether the empirical work presented in the dissertation supports the hypotheses presented in Chapter 2.

For Hypothesis 1, Figure 36 shows that the patents on magnetic inductive coupling technology continue to grow, while patents on magnetic resonance diminished in 2016. Furthermore, the significance of the microwave method was high in 2009, 2010, and 2012 but decreased afterward. The decrease in the topic significance may have occurred because the microwave method is harmful to the human body. Therefore, it is reasonable to state that the dissertation supports Hypothesis 1.

Hypotheses 2 through 4 can be examined using Table 25. For Hypothesis 2, the dissertation found that VRIN KIPO patents have lower average VRIN attributes than the VRIN USPTO patents; therefore, the dissertation supports Hypothesis 2. For Hypothesis 3, VRIN KIPO patents have lower average value and inimitability but higher average rarity and non-substitutability attributes than VRIN EPO patents; therefore, the dissertation fails to support Hypothesis 3. Finally, for Hypothesis 4, VRIN Korean public organization patents have higher average value, inimitability and non-substitutability attributes but lower average rarity level; therefore, the dissertation fails to support Hypothesis 4. Hypotheses 3 and 4 should be further examined because the number of VRIN patents for KIPO and EPO was too small.

At a glance, 46 VRIN patents out of 2,883 total patents seem very low as only 1.6% of the EV wireless charging patents have a competitive advantage in terms of VRIN attributes. However, given that the EV wireless charging technologies are immature and still in the development stage, the number of VRIN patents may not seem that low. As the technology becomes mature, more widely available to the public and more global standards for EV wireless charging are finalized, the number of VRIN attributes and the percentage of VRIN patents should go up. If more VRIN patents for KIPO (private and public assignees) and EPO can be found, it would provide better support and evidence for testing Hypotheses 3 and 4.

Table 31
Hypotheses Results of the Dissertation

Hypotheses	Results	Reason
H1: Since MI is the most mature technology widely used in other products such as mobile phones, more patents will be published on magnetic inductive coupling than magnetic resonance coupling or microwave (IR, RF) power transmission	Supported	Topic rankings show MI as one of the top 6 topics, and topic trends show more patents related to magnetic inductive coupling from 2016
H2: VRIN EV wireless charging patents filed in KIPO have lower average VRIN attributes than VRIN EV wireless charging patents filed in USPTO	Supported	VRIN KIPO patents have lower average VRIN attributes
H3: VRIN EV wireless charging patents filed in KIPO have lower average VRIN attributes than VRIN EV wireless charging patents filed in EPO	Failed to Support	VRIN KIPO patents have lower average value and inimitability attributes, but higher rarity and non-substitutability levels
H4: VRIN EV wireless charging patents filed by Korean Public organizations have lower average VRIN attributes than VRIN EV wireless charging patents filed by Korean private organizations	Failed to Support	VRIN Korean public organization patents have higher average value, inimitability and non-substitutability, but lower average rarity level

Chapter 6 Conclusion

6.1 Discussion

The dissertation integrated Barney's VRIN (valuable, rarity, inability to be imitated, and inability to be substituted) to identify resources with a competitive advantage to identify patents and emerging technologies that promise to generate licensing revenues and to examine the international competition in South Korea, the United States and Europe. The electric vehicle wireless charging technology was selected as a case study. The dissertation integrated two research techniques, topic trend analysis using topic modeling and patent mapping, to compare the competitive advantage, in terms of VRIN attributes, of EV wireless charging patents registered in Korean Intellectual Property Office (KIPO) and compares them to similar patents in the United States Patent and Trademark Office (USPTO) and European Patent Office (EPO).

Patents are competitive resources and are resources that have VRIN attributes. The dissertation used the number of forward citations to operationalize value and inability to be imitated, and the number of patent claims to operationalize the inability to be substituted. The research also operationalized rarity by computing the outlier scores for the document-term matrix in the patent abstracts. Finally, using the EV wireless charging patents published in KIPO, USPTO and EPO, the dissertation created a patent map to easily compare the VRIN attributes of the patents. The dissertation provided an alternative method to assess technology transfer and commercialization using patent information. The outcome shows that patents have a different competitive advantage level, and the VRIN patent mapping allows firms to compare their technologies to their competitors and governments to evaluate their R&D program outcomes as a performance-oriented variable.

The dissertation found several interesting points. First, regarding the topic trend analysis, the results show that topics 1 (magnetic_inductive), 3 (communication). 5 (charging). 11 (power_conversion), and 18 (wireless_power_transfer) are the highest rank among the patents. In addition, topic 8 (connector) was one of several topics that showed an increase in proportion between 2008-and 2020, which might tell that wireless charging may not yet be commercially ready for use.

Second, regarding the VRIN identification patent map, USPTO had the most VRIN patents with 40, and EPO and KIPO had three patents. In addition, Patents published in KIPO have lower VRIN levels than the USPTO patents and are comparable to those of the EPO patents. Also, it is difficult to state that Korean public organizations have lower VRIN attributes than Korean private organizations because 1) Korean public organizations have more VRIN patents than Korean private organizations, 2) Korean public organization patents have higher value and inimitability but lower rarity and non-substitutability and 3) a limited number of VRIN patents for KIPO.

Overall, the findings show that for South Korea to increase the number of technology transferred cases and the licensing revenue, the government would need to increase the VRIN attributes of the technology and create more patents with a competitive advantage. The dissertation is applicable by providing policymakers, funding agencies, and even R&D managers with a technique that may help forecast the emerging trends in a specific technology and assess its patents/technologies by comparing it to other similar technologies.

The dissertation also provides evidence that if Korea increases financial investments to improve the VRIN attributes of EV wireless charging patents in KIPO to the level of USPTO patents, then it can provide a way to improve the tech transfer performance in the EV case. However, the primary focus for South Korea should be increasing the number of VRIN patents in the field of EV wireless charging patents. In addition, the dissertation found 46 patents with a competitive advantage in terms of VRIN attributes. If funding agencies and government can focus on investing in the 46 patents, it can improve technology transfer performance and create a higher likelihood of commercialization success. Also, it can likely alleviate technology resistance because it provides objective means for identifying patented technologies with VRIN and competitive advantage. Once end-users have knowledge of the wireless charging technologies as shared by experts, then end-users would likely be less resistant to adapt.

6.1.1 EV Industry and Policy Implications

As technology advances more rapidly and becomes essential to our daily lives, as seen during the pandemic, firms must focus on staying competitive, and governments must help firms by creating an ideal environment for R&D, technology transfer and commercialization. The key to staying competitive in this rapidly changing environment is having a sustainable competitive advantage of the firms' resources. When emerging technologies are identified and understand that patents can have different performances in technology transfer and commercialization, government funding should be directed toward these specific technologies to give the industry a competitive advantage and optimize the use of R&D funds. Moreover, VRIN patent mapping and topic trend analysis should be tools to investigate where R&D and technology transfer marketing dollars should be best spent for tech firms to gain a better competitive advantage.

The Korean government's R&D investment in the public and private sectors totaled 93.072 trillion in 2020 (MSIT, 2021). Therefore, the Korean government, technology transfer and R&D practitioners should use this toolkit to better identify what technologies to invest its R&D and marketing funds in. This tool can help agencies spend R&D money more wisely, efficiently, and effectively. In addition, the toolkit can be run frequently to reflect the rapidly changing technological advances and be used in any industry for any patented technology.

The dissertation's EV industry and policy implications can be summarized as follows. First, to increase the technology transfer licensing revenue for universities and public research institutes, the Korean government must emphasize the importance of the competitive advantage of patents. It is necessary to conduct a performance-oriented assessment of the R&D support programs and evaluate the universities and public research institutes on the qualitative performance instead of the quantitative performance to increase the technology transfer licensing revenue of universities and public research institutes' patents. Moreover, the South Korean government must emphasize the VRIN attributes of patents and not the number of patents published at a university or a public research institute. When emerging technologies are identified and understand that patents can have different performances in technology transfer and commercialization, government funding should be directed toward these specific technologies to give the industry a competitive advantage and optimize the use of R&D funds.

Second, Korean universities and public research institutes must enhance their qualitative performance of the R&D outcomes, especially in the EV wireless charging area. According to the dissertation, only two out of two hundred thirty-three university and public research institute patents have shown VRIN attributes. For South Korea to compete with its competitors, the VRIN attributes of the patents must be enhanced. KIPO should also strictly ask for Korean and English versions of the abstract to provide meaningful information about the patents.

Third, South Korean firms are investing in the growth of the EV industry. For example, three Korean conglomerates have pledged to invest $35 billion in EV batteries to compete with China and Japan (Park and Lee, 2021), while Hyundai signed a memorandum of understanding (MOU) with the South Korean government and industry partners to demo EV battery leasing program (Hyundai, 2021b). The South Korean government should provide more funding and support for the EV industry, especially EV charging technology. As Kim et al. (2018), there must be a new method of EV wireless charging developed that has the advantages of both the MI and MR methods: high efficiency, power transmission that matches the government standards of 11 kw and longer transmission distance.

Fourth, governments worldwide play a vital role in growing and deploying the wireless charging infrastructure in the EV industry. Currently, there are too many charging standards and plug types, and thus, it confuses current and potential users. While it may be difficult to unify the different EV charging standards at the current stage, limiting the number of new charging standards is necessary as wireless, and various charging methods become available.

6.2 Research Limitations and Future Research

The dissertation addressed South Korea's low performance in technology transfer due to the low VRIN attributes of the patents filed by South Korea's public organizations compared to patents filed by Korean private organizations or international organizations. Thus, the VRIN addresses one area, the strength of patents or technology, of the technology transfer environment in Korea. However, there may be other reasons, such as cultural differences related to creativity, entrepreneurship, open innovation, and the role of public organizations that affect the technology transfer environment.

The EV wireless charging system is a complementary good, a product dependent on other products, such as power management software, batteries, coupling devices, connectors, vehicle-to-grid (V2G), and more. Therefore, while the dissertation used wireless charging-related patents to test the methodology, patent maps for batteries, power management software, and V2G technologies can be examined in future research.

The dissertation examined the patents filed in the EPO, KIPO and the USPTO but did not examine patents filed in China, which was stated to have the world's largest electric car market in 2019. Furthermore, EV charging systems are complex, with broader feasibility factors than just patents and technologies. There are standards-setting differences among government/countries, industries, and end-users. Charging systems raise an issue of "infrastructure" and are intricately related to government/municipal budgetary and political leveraging and the influence of standards bodies such as the Society of Automotive Engineers (SAE) and European EV Plug Alliance. The EV market size depends on the number of EVs charged at a station. Vehicles could stop at any gas station to refill their "battery," but with EVs, three main plugs are in use with two (soon to be three different charging networks) different stories today. How the EV charging infrastructure and patented technologies can co-evolve remains for future research.

The dissertation conducted a topic modeling but did not validate the results through an expert validation process. Topic modeling is an unsupervised analysis tool that leads to creative interpretation. However, the modeling process does not justify the interpretation and adequacy of topics, and therefore, a validation process is important as it provides an assessment tool for topics. With a validation process of the topic modeling, the result of the topic trend analysis would be more accurate. Therefore, a validation for topics must be implemented in future research.

Finding variables to measure the non-substitutability and rarity of patents remains a challenge. The dissertation used the number of claims to measure the non-substitutability of patents and outlier scores as rarity levels because previous literature stated that the number of claims was used for non-substitutability; however, the questionnaire results did not agree with the dissertation that the variables were good indicators of non-substitutability and rarity of patents. The use of the number of claims is the biggest concern for future research, given that the survey responses from experts reflected this concern. How the non-substitutability of patents can be operationalized remains to be answered for future research.

Another factor of the patent map that should be examined is the threshold value that determines the VRIN attributes. The dissertation used the default 50% or 0.5 as the threshold value, but as stated before, it is best to conduct the threshold level for each variable in machine learning. Therefore, in the future, it would be interesting to examine the threshold value of the number of claims, the number of forward citations and the outlier scores and compare how the newly created patent map with a different threshold value for VRIN attributes differs from the current patent map.

The validation process can be improved in future studies. For example, the questions could be more open-ended and have more questions regarding the variable measurements of the VRIN attributes and patent mapping. Furthermore, the questionnaire should be collected with more reliable sources instead of Google Forms because it requires the experts to log in to their Gmail accounts, limiting the experts to participate in the questionnaire. In addition, interviews with EV-related firms should also be considered as a tool that can be applied to private technology transfers. Also, interviews with consumers on their use of EVs and their resistance to EVs to examine the lack of EV adoption and how technology with more competitive advantage can help alleviate the resistance.

Finally, while the dissertation successfully created the VRIN patent map, the techniques can be further improved. For example, the local outlier factoring was used to identify the rarity level. In future research, other machine learning and artificial intelligence techniques such as recurrent neural networks (RNN) could be considered to create a more intelligent and efficient tool. A more advanced tool could provide better evidence for the rarity of patents, something that the experts did not agree with, and support the importance of the qualitative performance of the technology transfer and commercialization. To further improve the toolkit, sales trends could also be examined in addition to patents to reflect the rapidly changing technological advances.

Nonetheless, this dissertation successfully compared South Korea’s technology transfer environment to the United States and Europe by examining the value, rarity, inimitability, and non-substitutability attributes of EV wireless charging-related patents. The topic trend analysis helped to examine a large set of documents quickly by examining the changes in the significance over the years. While the competitive advantages of EV wireless charging patents can be calculated using the normalized scores of the number of claims, the forward citations and the outlier scores, the patent mapping helps to combine and compare a large set of patent data easily and identify the VRIN patents quickly and more efficiently. One of the limitations of the patent map is that because it takes up to five years for a patent to collect its forward citations, the patent map cannot examine the competitive advantages of up-to-date patents. However, suppose patent value and patent inimitability can be operationalized from newly published patents. In that case, the toolkit can also provide a method to examine and compare competitive advantage in terms of VRIN attributes of new patents. Furthermore, the toolkit developed in this dissertation can also be expanded as the methodology can be applied to other technologies, such as fuel cells and semiconductors, or other sectors, such as the pharmaceutical industry.

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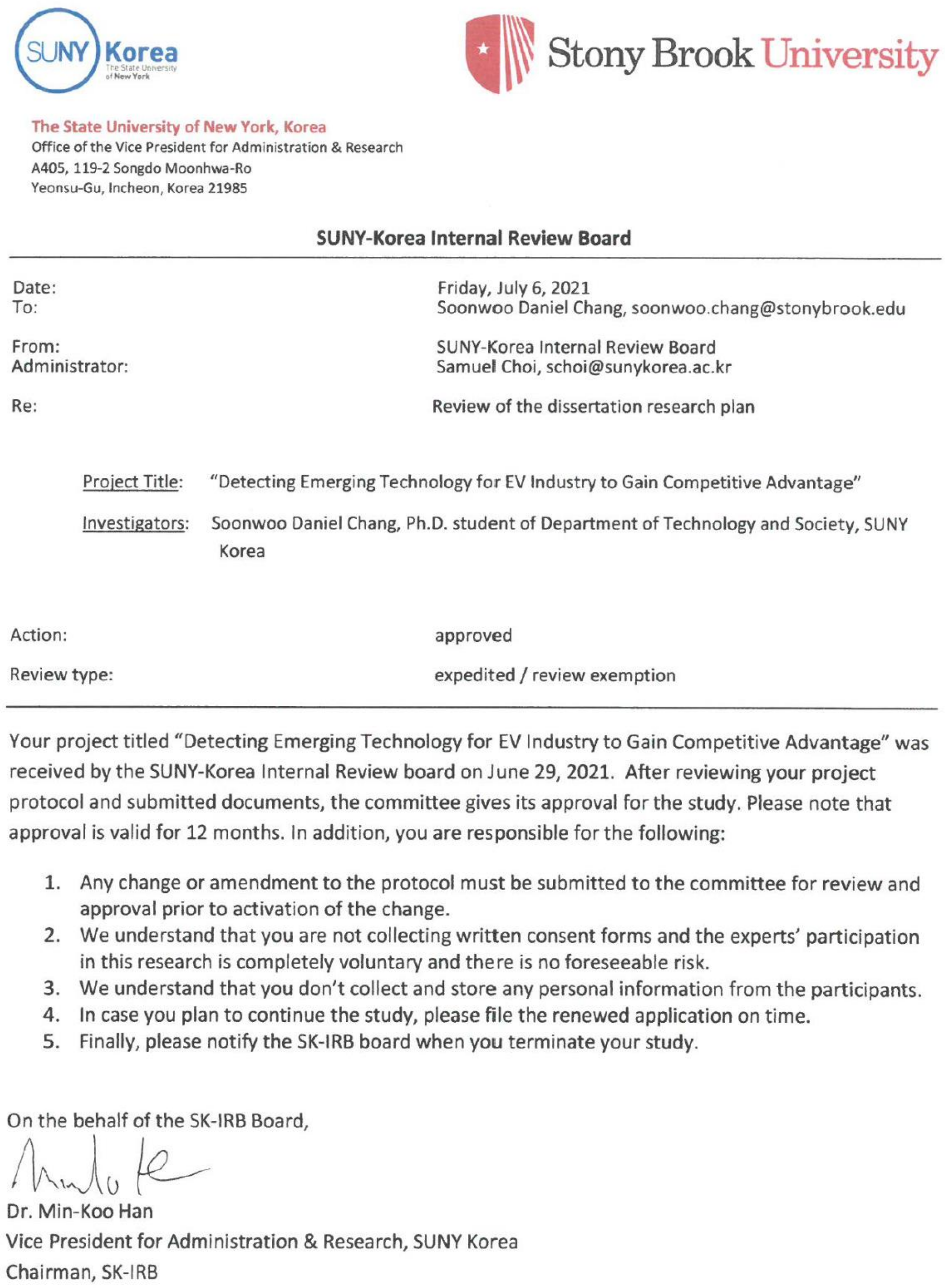
Appendix

Appendix A – IRB



SUNY Korea
The State University of New York

Stony Brook University

The State University of New York, Korea
Office of the Vice President for Administration & Research
A405, 119-2 Songdo Moonhwa-Ro
Yeonsu-Gu, Incheon, Korea 21985

SUNY-Korea Internal Review Board

Date:	Friday, July 6, 2021
To:	Soonwoo Daniel Chang, soonwoo.chang@stonybrook.edu
From:	SUNY-Korea Internal Review Board
Administrator:	Samuel Choi, schoi@sunykorea.ac.kr
Re:	Review of the dissertation research plan

Project Title: "Detecting Emerging Technology for EV Industry to Gain Competitive Advantage"

Investigators: Soonwoo Daniel Chang, Ph.D. student of Department of Technology and Society, SUNY Korea

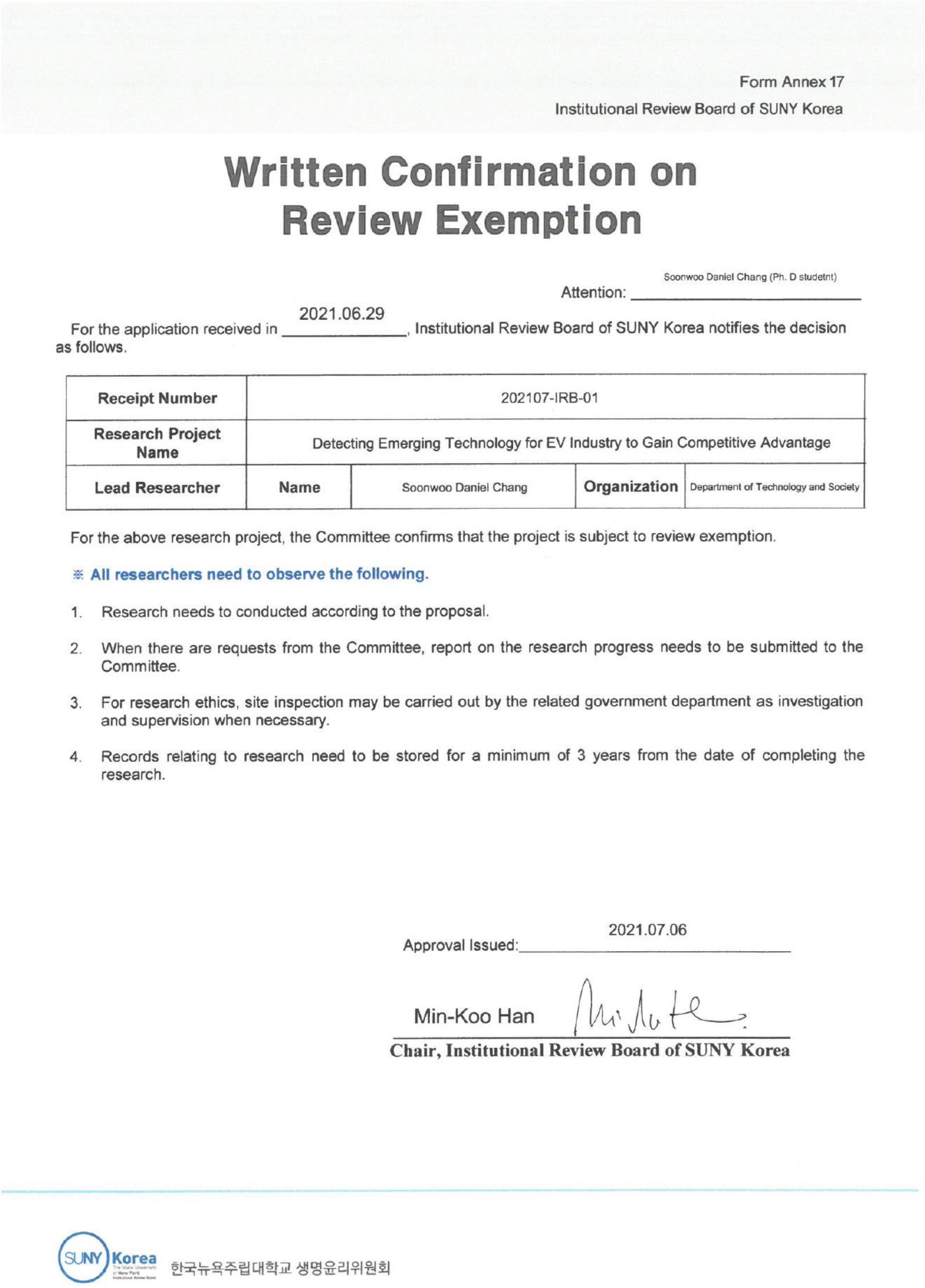
Action:	approved
Review type:	expedited / review exemption

Your project titled "Detecting Emerging Technology for EV Industry to Gain Competitive Advantage" was received by the SUNY-Korea Internal Review board on June 29, 2021. After reviewing your project protocol and submitted documents, the committee gives its approval for the study. Please note that approval is valid for 12 months. In addition, you are responsible for the following:

1. Any change or amendment to the protocol must be submitted to the committee for review and approval prior to activation of the change.
2. We understand that you are not collecting written consent forms and the experts' participation in this research is completely voluntary and there is no foreseeable risk.
3. We understand that you don't collect and store any personal information from the participants.
4. In case you plan to continue the study, please file the renewed application on time.
5. Finally, please notify the SK-IRB board when you terminate your study.

On the behalf of the SK-IRB Board,

Dr. Min-Koo Han
Vice President for Administration & Research, SUNY Korea
Chairman, SK-IRB



Form Annex 17
Institutional Review Board of SUNY Korea

Written Confirmation on Review Exemption

Attention: Soonwoo Daniel Chang (Ph. D studetnt)

For the application received in 2021.06.29, Institutional Review Board of SUNY Korea notifies the decision as follows.

Receipt Number	202107-IRB-01				
Research Project Name	Detecting Emerging Technology for EV Industry to Gain Competitive Advantage				
Lead Researcher	**Name**	Soonwoo Daniel Chang	**Organization**	Department of Technology and Society	

For the above research project, the Committee confirms that the project is subject to review exemption.

※ All researchers need to observe the following.

1. Research needs to conducted according to the proposal.
2. When there are requests from the Committee, report on the research progress needs to be submitted to the Committee.
3. For research ethics, site inspection may be carried out by the related government department as investigation and supervision when necessary.
4. Records relating to research need to be stored for a minimum of 3 years from the date of completing the research.

Approval Issued: 2021.07.06

Min-Koo Han

Chair, Institutional Review Board of SUNY Korea

SUNY Korea 한국뉴욕주립대학교 생명윤리위원회

Appendix B - Questionnaire

Questionnaires for Detecting Emerging Technology for EV Industry to Gain Competitive Advantage

You are invited to participate in this research questionnaire, "Detecting Emerging Technology for EV Industry to Gain Competitive Advantage."

The questionnaire was designed for a study conducted by Daniel Soonwoo Chang as a part of the Dissertation at Stony Brook (SUNY Korea) University. This research aims to provide R&D teams with a way to identify patents with sustained competitive advantage attributes, thus creating a higher likelihood of commercialization success.

*Definition

Meaning of inimitable patents:
Inimitable patents are patents that are not easily imitated by other technologies
Meaning of non-substitutable patents:
Non-substitutable patents are patents that other alternative technologies cannot substitute

During this questionnaire, you will be asked to review the identified valuable, rare, inimitable, and non-substitutable (VRIN) attributes of the electric vehicle (EV) wireless charging-related patents according to your expertise. The results will be used to validate the patent map created. In addition, we want you to validate the operational validity of the patent map.

Your participation in this study is entirely voluntary. Your information will be coded and will remain confidential. There are no known risks associated with participation in this study.

The whole questionnaire would take around ten to twenty minutes to complete.

This survey is being conducted as unsponsored doctoral thesis research. The questionnaire was created using Creswell's (2015) mixed-methods approach and Sargent's (2011; 2014) verification and validation of the simulation model approach.

You have been invited to this questionnaire as one of the following four professions.

1) University and public research institute TTO staff
2) Private and public research division involved in EV
3) Engineering, business, and law professors that conduct tech transfer and intellectual property research
4) Patent attorney

Your responses are valuable. Please note:
- All of your responses will be confidential and will be conducted anonymously.
- All responses are voluntary, and you can stop responding during the questionnaire.
- Since your personal information is not stored with the response, you will not be able to cancel the response after submitting the final questionnaire response.

If you have any questions concerning this research experiment, or if you would like to receive the results of the study, please contact Daniel Soonwoo Chang at soonwoo.chang@stonybrook.edu.

If you have any questions about your rights as a survey respondent, please contact SUNY Korea University Institutional Ethics Committee.

If you agree to participate, please check the box below, and continue.

☐ I hereby confirm my participation in this questionnaire and agree to fill out as much of the information as possible.

Part 1: Brief Introduction of the Dissertation - 5 Ws + 1H

What is the dissertation about?

Patents are valuable and rare by definition. However, not all patents have the same value and rarity level. The dissertation examines the sustained competitive advantage attributes of EV charging system patents using Barney's Resource-based View (RBV), and the value, rarity, inimitable, and non-substitutable (VRIN) attributes theoretical foundation. The theory stated that a firm could have a sustained competitive advantage if its resources have VRIN attributes. VRIN stands for valuable, rare, inimitable, and non-substitutable. The dissertation used the EV industry as a case study, focusing on the wireless charging technology for EVs.

*Definition

Meaning of inimitable patents:
Inimitable patents are patents that are not easily imitated by other technologies
Meaning of non-substitutable patents
Non-substitutable patents are patents that cannot be substituted by other alternative technologies

According to Park and Park (2017), the technology transfer cases of 2012 and the technology transfer licensing revenue of 2013 in Korea were lower than in the United States. Therefore, the dissertation hypothesized that VRIN attributes of EV charging system patents owned by the Korean public organizations are lower than the EV charging system patents owned by the US assignees and patents owned by private Korean organizations.

Where are the patents from?

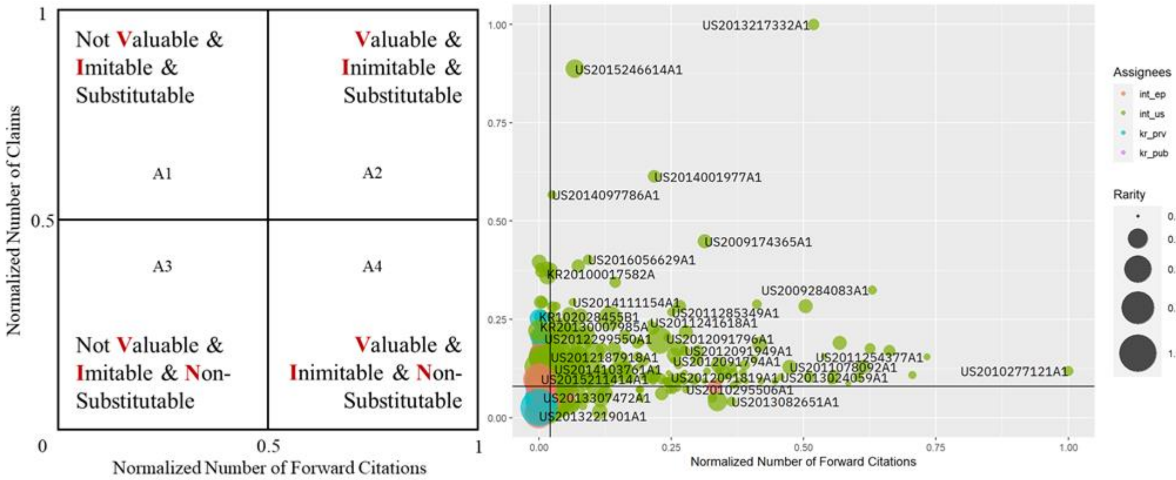
The dissertation focuses on the patents filed by the Korean public research institutions (including universities) and compares them to patents filed in the USPTO and the EPO.

When were the patents filed?

Lim and Kim (2020) stated that three patents related to electric vehicles (EV) were first filed in Korea in 2008. In addition, Narin and Olivastro (1993) found that citations to earlier patents peak when the patents are three to five years in age. Therefore, the dissertation used patents from 2008 to 2017 to develop the patent map.

Why is the dissertation important?

With the created patent map, the user can compare the competitive advantage, in terms of the VRIN attributes, of similar technology patents in one diagram. By comparing the VRIN attributes, the user can identify patents with a more competitive advantage, thus showing more likelihood of being transferred and commercialized. In addition, if the patent map result can be validated, it can provide more meaningful information.



VRIN Patent Identification Map Layout

Do not run away, please :) I know this looks intimidating, but you will simply be asked whether you have ever seen or used a patent map.

How was the dissertation conducted?

The purpose of the dissertation is to identify patents with sustained competitive advantage through constructing a valuable-rare-inimitable-non substitutable (VRIN) patent identification map. The patent map uses a normalized number of forward citations and a normalized number of claims as axes. Furthermore, the patent map uses the average values of the axes to help categorize the four quadrants of patent types: Inimitable & Non-Substitutable, Inimitable & Substitutable, Imitable & Non-Substitutable, Imitable & Substitutable. Figure 1 shows the VRIN identification map layout. Patents located on the bottom right area (A4) are patents with high value, inimitability and non-substitutability. In order for these patents to have a high competitive advantage, their rarity level should be high as well. Therefore, for the dissertation, it is important to examine which patents are located in the A4 area and how many of them have a rarity level higher than the average rarity level of the whole data set.

Who should be interested in the dissertation?

The dissertation enables policymakers, funding agencies, and even R&D managers to identify patents with sustained competitive advantage attributes, thus creating a higher likelihood of commercialization success.

Part 2: Questionnaire

Section 1: Affiliated Institution

Q1) Please select one of the following three areas of expertise.

☐ Technology Transfer Offices (TTOs) / Technology Licensing Offices (TLOs)

☐ Firm involved in Electric Vehicle technology
☐ Research institute involved in Electric Vehicle technology
☐ University faculty involved in intellectual property
☐ Others. Click here to enter text.

Q1.1) If you are a university faculty involved in intellectual property, what department are you affiliated to?

☐ Business
☐ Engineering
☐ Law
☐ Others. Click here to enter text.

Section 2: Working with Patents

Q2) Have you ever analyzed patent information?
☐ Yes (Move to Q3)
☐ No (Move to Q4)

Q3) If Yes to Q2, what was the main purpose of analyzing patent information?
Click here to enter text.

Q3) If No to Q2, what is the main reason that you have not used patent information?
☐ Difficulty of collecting patent information
☐ Difficulty of conducting patent analysis
☐ Difficulty of validating patent analysis results
☐ Difficulty of understanding the patent analysis result
☐ Do not think meaningful information can be extracted with patent information
☐ Other

* Section 3 asks about the methods that you have used to analyze patents. Since you have answered Q2 as No, you will skip section 3 and be directed to Section 4.

*Direction

- For those who said **Yes to Q2**. **Please go onto section 3**, Current Method of Patent Analysis
- For those who said **No to Q2**, **Please go onto section 4**, Comparing Patents

Section 3: Current Method of Patent Analysis

Q4) What patent variables have you used to analyze?

☐ Patent Abstract
☐ Patent Claims
☐ Number of Patent Claims
☐ Number of Forward/Backward Citations
☐ Assignees
☐ Inventors
☐ None
☐ Other

Q5) What methods have you used to analyze patent information?

Click here to enter text.

Q6) What were some drawbacks that the analysis method(s) you used have?

Click here to enter text.

Q7) Are you familiar with text analyses of patent abstracts?

☐ Yes
☐ No

Q8) Have you ever used patent mapping analysis?

☐ Yes
☐ No

Q8.1) Was it difficult to understand the patent map results? Did you get the results you wanted? Were the results helpful? Please describe your experience in detail.

Click here to enter text.

*Direction

- Continue to **Section 4**, Comparing Patents

Section 4: Comparing Patents

Q9) Have you heard about comparing patents' competitive advantage?

☐ Yes
☐ No

Q10) Do you think patents can have different values, rarity, inimitable and non-substitutable levels?

☐ Yes
☐ No

*Definition

Meaning of Substitutable Patents

- Substitutable patents are patents that can be substituted by other alternative technologies

Meaning of Patent Claims

- Patent claims refer to the technical features of the invention to be protected, and the number of claims means the total number of technical features of the patent.

Q11) Do you think it is reasonable to say that patents with more number of claims make patents more substitutable?

☐ Yes
☐ No

*Definition

Meaning of Imitable Patents

- Imitable patents are patents that can be easily imitated using different technologies

Meaning of Forward Citations

- Forward citations refer to the number of cited subsequent patents

Q12) Do you think it is reasonable to say that patents with more number of forward citations make patents more valuable and inimitable?

☐ Yes
☐ No

*Definition

Meaning of rare patents and anomalies

- Patents are rare by definition, but not all patents have the same "rarity" value because rare patents are patents that are hard to find among competitors.
- Anomalies are rare events (Latecki, 2007) and are defined as noises with high outlier levels and may provide meaningful information (Aggarwal, 2017).

Q13) Do you think detecting anomalies or extremely high outliers can help detect higher rarity in patents?

☐ Yes
☐ No

Section 5: Regarding the New Patent Map

*Direction

- This section is about the patent map created through the dissertation using the R program and its packages.

*Explanation

- Figure 2 shows the whole patent map for EV wireless charging technology
- What the research is interested in are the patents that are located in area A4

- As stated above, patents located in A4 do not automatically equal to patents with a competitive advantage. Patents with a high rarity level (those with bigger circles) are the ones that have a competitive advantage. Those patents are shown in Figure 3.

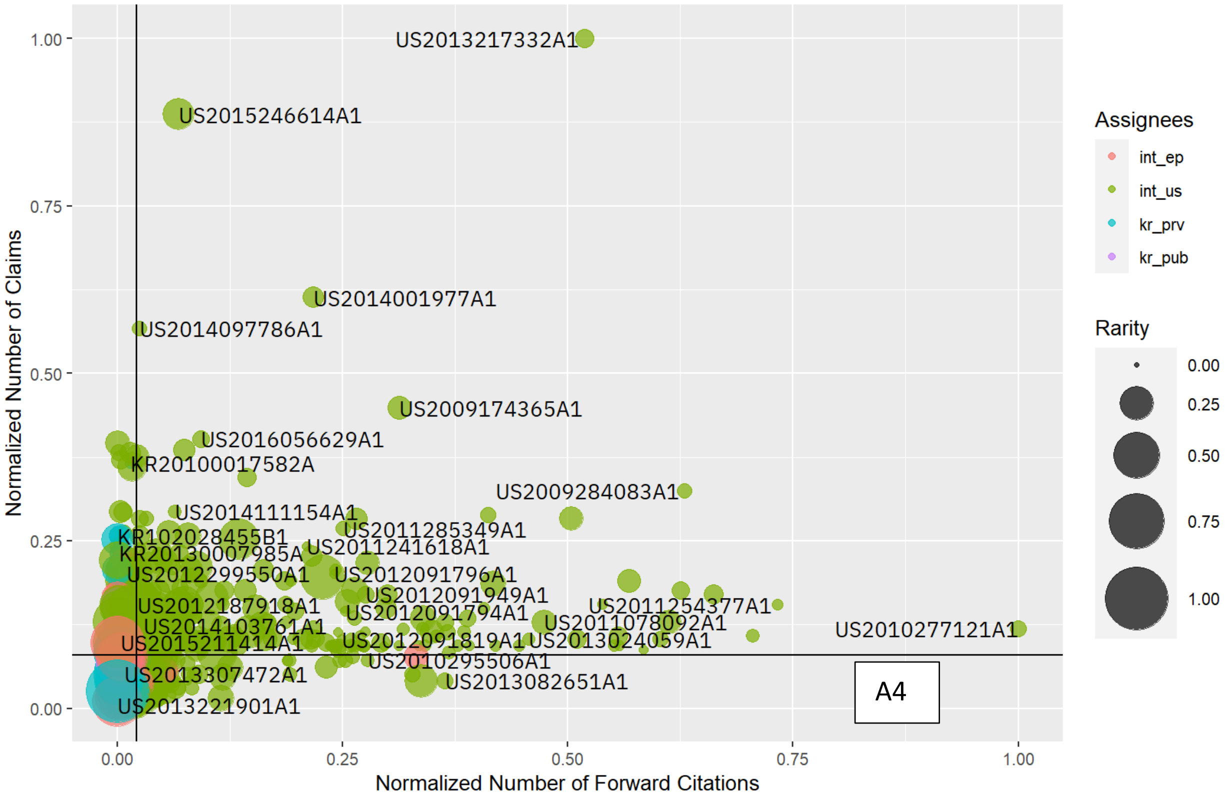


Figure 2: VRIN Patent Identification Map

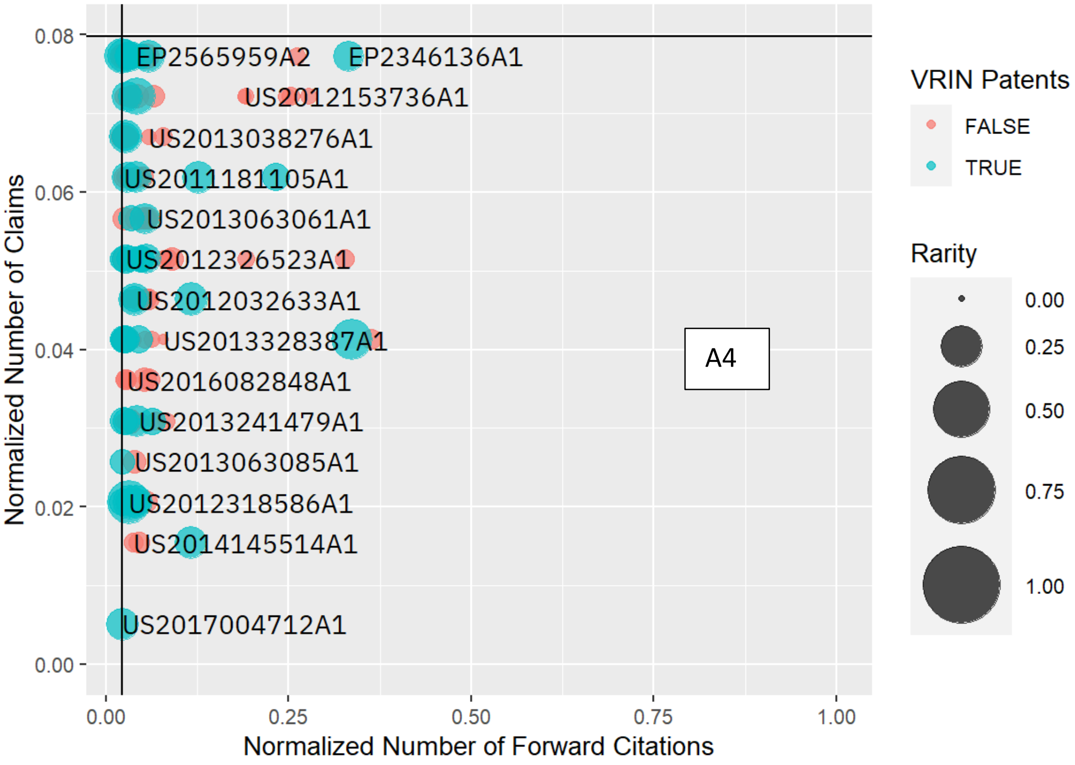


Figure 3: Identifying VRIN patents in Area Q4

Q14) Have you ever seen these visualizations? Have you ever used a patent map?

☐ Yes
☐ No

Q14.1) If yes, for what purpose have you used the patent map? Click here to enter text.

Q15) Given the explanation of how patent maps are used, in your opinion, do you think a patent map such as this can provide meaningful information and be used in identifying patents with a competitive advantage?

☐ Yes
☐ No

Q16) Given the explanation of how patent maps are used, in your opinion, do you think patents with more competitive advantage can have a higher likelihood of being transferred and show promise for generating licensing revenue?

☐ Yes
☐ No

Section 6: About EVs and EV Charging Stations

Q17) Are you knowledgeable in EVs? Charging Stations?

☐ Yes
☐ No

Q18) If yes, what are the future directions of EVs and EV charging stations, in your opinion? Bright or Bleak Outlook? Click here to enter text.

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