Advanced Technology for Drone System Development, Operation and Management

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Abstract. This study is a trend analysis of the master's and doctoral theses and academic journals bout drones in Korea that are published or nominated to be published in KCI (Korea Citation Index). The published study analyzed were 350 masters' and doctoral theses and 591 journals indexed using the keywords "drone" and "multi-copter" from RISS (http://www.riss.kr) from 2014 to September 2021. Since drones are spreading fast and being applied in many areas, its demand is increasing in different sectors and, thus, it is necessary to analyze the trend. The analysis will serve as basic data for subsequent studies. The results are as follow. There are five times more male researchers than female researchers. The number of publications grows as time passes. There are more quantitative studies than qualitative studies. The study scope mostly covers the technical area. Though the references tend to show similar dispersion, most of the studies were carried out in Seoul. In conclusion, this trend analysis implies that drones, being connected to the Fourth Industrial Revolution technology, have constantly developed at the center of the social and environmental changes, while leading the autonomous and unmanned technology.

Keywords: Drone, dissertation, thesis, academic study, trend analysis

1. Introduction

The Ministry of Land, Infrastructure and Transport announced the "Drone Industry Development Plan 2.0" in 2020. This policy aims to foster core companies and accelerate drone services to produce tangible results such as qualitative growth of the drone industry and commercialization of business models.

It also promotes fostering K-drone brand companies and activating the drone industry of Korea to lead the drone market (Ministry of Land, 2020). In line with the goal of becoming the top five drone technology competitors, it appears to prove the government's resolution to establish the drone industry as a national/regional strategic industry, after the government has implemented the "Basic Program for Drone Industry Development (2017~2026)," "Roadmap for Drone Activation Support and Innovative Growth Power Action Plan (2018)," and "Drone Use Promotion & Infrastructure Development Act (2019)," which were the main subjects of expanding infrastructure and company aid hub models such as developing early market based on public demands, commercializing drones, constructing K-drone system, innovating regulations, promoting practical operations as Sandbox pilot programs, and expanding development/certification/license. Presenting the direction for the drone industry constantly through such policies may lead the revitalization of local economy by creating the safe ecosystem. It appears to reflect that the public/private demands are growing gradually (Ministry of Land, 2017).

Davos Forum, the World Economic Forum, expected that drones will not just be means of mobility but also a technical drive force of the Fourth Industrial Revolution, being merged into various industries such as collecting, processing, distributing, and applying information (Taejin, 2017).

The Fourth Industrial Revolution is based on hyper-function, hyper-connectivity, and hyper- convergence. It is predictable that scientific fields such as artificial intelligence and robotics would see innovative changes and various convergence technologies would accelerate changes in social environment and structure.

The status of drone applications and development shows that it has been influenced by the result of the Fourth Industrial Revolution across the whole area, from manufacturing parts with 3D printing technology, autonomous flying and 5G that enables it, machine learning and controlling technology, IoT, and big data, Therefore, while drones are to drive the Fourth Industrial Revolution as a part of it, they would enlarge its influence and applications even more, backed up by the results of this new industrial era (Taejin, 2017).

Thereby, the Fourth Industrial Revolution is leading the changes in the social structure as it accelerates due to the improvement of cloud technology, mobility, and machine intelligence. Such changes lead to autonomous robot technology through convergence technologies. The perspective on labor is expected to change, as well. It is expected that the way of thinking and direction in life would change rapidly according to the changes in society.

Ever since the pandemic in 2019, global economic downturn has been prolonged, and crisis increases throughout the industry. Meanwhile, drone technology was converged into other industries – which is a technical characteristic of the Fourth Industrial Revolution – to be applied as quarantine tools and social distancing guide. The separation of face-to-face contact spaces and the "untact" trend of the post-COVID are likely to trigger the convergence technology of the Fourth Industrial Revolution and the industrial ecosystem such as drones (Gyeongin llbo, 2021).

A drone refers to a helicopter-shaped aircraft that can be piloted on fields, through the guidance of radio waves. As its application has been spread to various fields, the term "drone" started to be used widely (Trouble Shooter, 2020). It is assumed that drones started to popularize in 2010 when Parrot in France launched a small drone. The compact size contributed to the convenience of mobility, price reduction, and steady flying through the applications and wireless internet that enabled anyone to control drones easily.

Before, more than 90% of the drone applications were for the military use. Now, drones are being used for various purposes, restructuring the market, especially for the commercial use. The drone market, which was only $ 6.4 billion in 2014, is expected to increase to $ 11.5 billion by 2024. The cumulative sales during the period are expected to reach $ 91 billion. The Association for Unmanned Vehicle Systems International (AUVSI) estimates that the economic benefits the U.S. would gain from drone from 2015 to 2025 would reach $ 82.1 billion. It also expected that drone industry would create about 10,000 jobs (Sangdeok et al., 2017).

According to the Japan Research Institute's, data, Gartner, a global IT consulting company, expected that the "inspection" sector would account for 30% of the commercial drone market. Yano Research Institute shares the same prospect as it expects "inspection", "examination", and "measurement" sectors would grow in drone industry. It also predicted that "oil/gas", "energy", "infrastructure", and "transportation" sectors would grow rapidly, while expecting that drones would be applied the most actively in the agricultural market.

PwC Consulting expected that drones would be used effectively in the fields of infrastructure, logistics, media, entertainment, telecommunication, base station management, and security. It also predicted that drones would be applied to the field of mining and agriculture through technology convergence. Alied Market Research estimated that the compact drone market will grow at an annual average of 11.8% (JIR, 2018).

Thomas Frey (Frey, 2014). director of DaVinci Institute, predicted that the demands for drones will increase until 2030. Frey also suggested that 192 new applications and professions in 24 fields that may use drones such as marketing, sports, library, education, military, spy, health care, entertainment, emergency service, real estate, travel, alarm system, police, game, new reporting, delivery, and agriculture.

CBINSIGHTS (2020) reported that high-risk and high-cost tasks are likely to be replaced by drones, presenting the examples of drones being used. The examples proved that using drones for the whole process of collecting and providing data, from advertisement to infrastructure development and individual mobility, is safe and efficient. Thereby, drones are touted as to be economically efficient and applicable to various fields (CB Insights, 2020).

As the drone market is expanding to the field of individual customer and services, many different business related to drones are emerging. Global IT companies such as Google, Facebook, Intel, Qualcomm, and Sony are aggressively entering into the drone market by acquiring or investing in drone companies. Major logistics companies like Amazon.com and DHL announced their plans to use drone for the delivery service (Seil, 2005).

Domestic drone market is becoming the cornerstone for Korea Aerospace Industries (KAI). Statistical data of the TS national flight qualification shows that the number of ultralight plane pilot licenses registered from 2017, when the drone industry policies were established, to June 30, 2021 was 52,424 cases, which has increased more than 12 times of the 4,137 cases that were registered up to 2016 (Korea Transportation Safety Authority, 2017).

Recently, drones have started being used mainly for the agricultural pest control, which is the primary industrial work. Being applied to the various areas including construction, measurement, observation, journalism, contents creation, spatial information colligation, and educational and environmental monitoring, the drone industry has been reformed through its function of replacing human labor.

In public areas, moreover, drone are used in the places and works where humans cannot access, proving its quick and broad scalability and excellent effectiveness. Drones cover not just disaster/accident sites but also weather observation, communication relay, monitoring and controlling illegal activities, construction, forest resources monitoring and cadastral investigation, air pollutant measurement, structure inspection and management, marine safety, and missing person search. While overcoming the limitations of performing difficult tasks through drones, the convenience of work has been amplified.

The government estimated that the global drone market will grow by 29% every year until 2026 (Sehun, 2021). Provided that domestic drone laws and regulations are improved and eased in line with such a global trend, demands in the domestic market will increase rapidly. Therefore, ever since 2019 when the Drone Act was enacted, each local government has been pushing ahead programs that use drones in various ways. Gyeonggi-do established unmanned vehicle-related ordinances quite early, taking preemptive actions with data-based policies (Myungjin, 2021).

Seoul introduced drones to the firefighting field, specifically of Seoul 119 Special Rescue Services and administrative works. Busan established "Busan Urban Management Drone System Development Ordinances" for the city management.

Daegu has promoted creating unmanned aerial vehicle complex, and Ulsan uses drones to forecast red tide. Chungcheongnam-do and Jeollabuk-do apply drones to agriculture, and Jeollanam-do is pushing forward for land alteration measurement and taking aerial images (Samcheol, 2016).

With such governmental push, the drone market of Korea has increased more than 6.5 times in four years. Nevertheless, Korea lacks world-class companies to lead sustainable drone business. The tendency to prefer Chinese drones and American software and the poor performances of local governments of using drones are pointed out as problems to be solved by political means (Ministry of Land, 2020).

Drones have constantly accomplished technical improvement in military, public, private, industrial, and academic areas, demonstrating its work efficiency. It is becoming a new tool to enrich human life even more. Technologies that apply drones provide a new labor environment for human to improve the quality of life by creating new industries and values. This will be the starting point for the sustainable future that builds organic relationships with the environment.

On the other hand, there are growing concerns domestically and internationally, about safety and security because of unauthorized drone use. Cases of invading personal privacy have been reported frequently, and there are always the risks of crashes and falls when drones are flying restricted area or at a low altitude without going through safety education. Drones are also abused for hacking and crimes. Therefore, it is necessary to secure safety measures and relevant policies to control such risks.

While there have been constant studies on drones, not a single study was done regarding the trends of the drone study. Ever since 2014, academic results have been reported through study in various fields. Sang-won Seo (Sangwon, 2014). received a master's degree in 2014 by embodying an autonomous flight drone platform.

Jung-whan Kim (Junghwan, 2016). received a doctoral degree in 2016 by suggesting military use of drones. The very first paper that was published in an academic journal was Pan-seob Shim, Sun-kyung Kim, and Jung-min Kim's study on the improved controller based on the G-sensor for flight drones (Digital Convergence, 2014). Drone studies have been focused on technical aspects such as development in the engineering field (Yumee, 2020)(Bohye, 2021).

There have been researches about drones such as military application plans (Hosung, 2020) (Cheolyoung, 2015), aerial photography and satellite images (Hyungki, Hyukjae, 2020) (Binghao, 2021), drone delivery route optimization (Aram, 2021), police search for missing person and counter terrorism (Jihoon, 2021)(Hyunho, 2020), agricultural facility maintenance and pesticide application (Jinkuk, 2019)(Kyawzayar, 2021), monitoring system using IoT-based unmanned vehicles or drones (Taekshin, 2019)(Yongah, 2018), security and safety (Woojin at al., 2020)(Sesun, 2019), disaster safety control (Youngseon, 2020), relevant laws and regulations (Sekwon at al., 2021), training/education and environment (Hoonchang,

2019)(Hyunghoon, 2019), and studies on the transportation field (Dohoon, 2021)(Jaekwang, 2020).

As drones account for a growing proportion of the overall part of our society, drone studies have been constantly increasing. It is necessary to figure out how many drone studies there are, how they are studied, and which fields of them are studied. Thus, this paper analyzed precedent studies from 2014 to September 30, 2021. It aims to sum up the study trends over the period and suggest basic data for subsequent studies.

2. Research Method

2.1. Study subject

The precedent studies that were finally selected for this study were 349 master's and doctoral theses and 591 journals. Among the Korean theses that are found in RISS and the journals published and nominated to be published at KCI and KCI superior journals, the ones with the keywords "drone" and "multi-copter" were selected. There were 744 theses that were searched by the two keywords and 349 of them, of which 297 were master's theses and 52 were doctoral theses, were selected as subjects. By the same keywords, 1,869 journals were found, and 591 of them were selected.

2.2. Research design

This study was conducted from March 20 to October 31, 2021. In March, an experts meeting was held to give feedbacks about the possibility of the study. To analyze the study data, this study searched Korean theses that are registered to RISS using the keywords "drone/s" and "multicopter/s" Data collection was conducted from April 1 to September 31, 2021. The collected data was analyzed from October 1 to 20, 2021, and the final aggregation was done by October 31, 2021.

3. Data Analysis

This study analyzed 349 Korean theses and 591 journals by the researchers' gender, the year that they were published, study method, study field, the institution that granted the degree, and the area where they were studied. It presented the frequency by the real numbers and the percentages, and the results by tables and graphs.

4. Results

4.1. Gender trends analysis

This study covered 349 theses, of which 297 of them are master's theses and 52 are doctoral theses. One male researcher both received the master's and doctoral degree in drone, thus, according to gender, the total number of researcher was 348 Among the 591 journals, there were five times more male researchers than female researchers

Table 1: Paper classification analysis table by gender

Gender	Journal	Master's	Doctoral	Sum(%)
M	503	247	48	798(85)
F	88	49	4	141(15)
Sum	591	296	52	939(100)

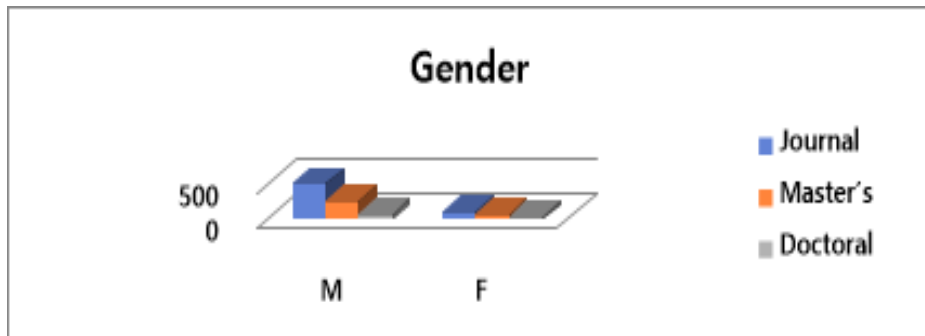
Fig. 1: Paper classification analysis graph by gender

4.2. Analysis of papers by year

Based on the trends the year the papers were published, in 2014, there were two master's theses and one doctoral thesis. In 2016, it started to increase to 13 master's theses and 2 doctoral theses. In 2017, drone studies started to be animated and tripled, with 41 master's theses and 6 doctoral theses. The number of master's theses being published has increased to 56 in 2018, 72 in 2019, 68 in 2020, and 40 in the first nine months of 2021.

The number of doctoral theses also increased to 8 in 2018, 11 in 2019, 12 in 2020, and 11 in the first nine months of 2021. Journals also have increased, starting from 5 in 2014 to 33 in 2016. In 2017, it tripled to 108 journals It has constantly increased to 126 in 2018, 129 in 2019, and 137 in 2020. There were 114 journals published 2021, and as of September, it is assumable that more journals may be published in the remaining three months.

Table 2: Number of papers per Yyear

Year	Journal	Master's	Doctoral	Sum(%)
2021	96	40	11	147(15.6)
2020	122	68	13	203(21.6)
2019	115	72	11	198(21.1)

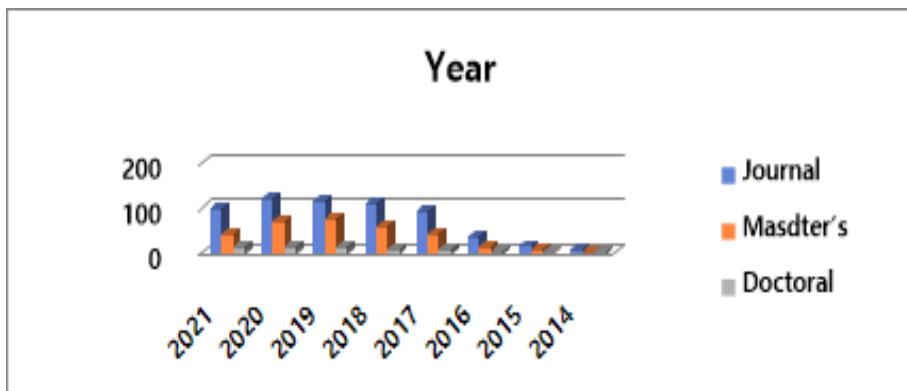| 2018 | 111 | 56 | 8 | 175(18.6) |
2017	92	41	6	139(14.8)
2016	33	13	2	48(5.1)
2015	15	5	0	20(2.1)
2014	7	2	1	10(1.1)
Sum	591	297	52	940(100)

Fig. 2: Number of papers per year

4.3. Analysis by study method

As a result of classifying the theses and journals by the study method, master's theses were classified in the order of quantitative study, literature study, mixed study, and qualitative study.

Doctoral theses were classified in the order of quantitative study, literature study, qualitative study, and mixed study. Journals were classified in the order of quantitative study, literature study, mixed study, and qualitative study.

Table 3: Tendency of study methods for master's and doctoral papers

Study Method	Journal	Master's	Doctoral	Sum(%)
Quantitative	444	244	44	732(77.9)
Qualitative	4	1	2	7(0.7)
Literature	138	47	5	190(20.2)
Mixed	5	5	1	11(1.2)

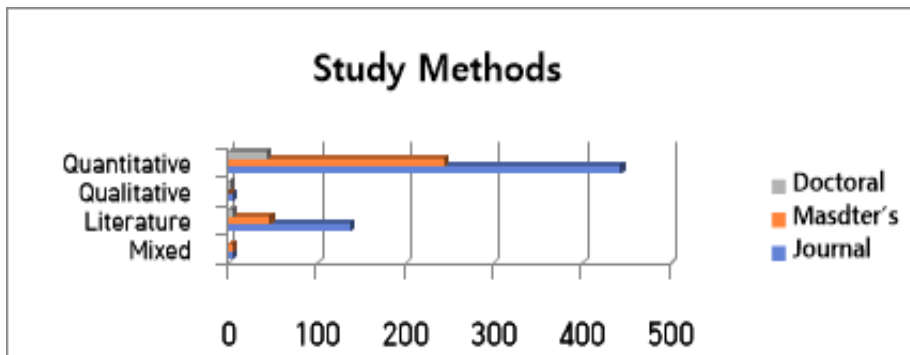| Sum	591	297	52	940(100)

Fig. 3: Tendency of study methods for master's and doctoral papers

By study period, the papers were divided into three phases - Phase 1 (2014 to 2016), Phase 2 (2017 to 2019), and Phase 3 (2020 to 2021). As a result, when the drone studies started in 2014, most of the theses were conducted quantitatively. It suggests that drones are being applied more broadly throughout various industries such as police, construction, fire fighting, security, safety, transportation, logistics, agriculture, marine, and even education, and the experimental studies are being conducted, focusing on various applications of drones. In addition, literature studies are discussing about implementing laws and regulations. It implies that there have been discussions on how the destructive power of drones can protect human life safely in the institutional system.

Table 4: Tendency of study methods by period

Year	'14~'16	'17~'19	'20~'21	Sum(%)
Journal	55	318	218	591(100)
Quantitative	31	247	166	444(75.1)
Qualitative	1	1	2	4(0.7)
Literature	23	67	48	138(23.4)
Mixed	0	3	2	5(0.8)
Master's	20	169	108	397(100)
Quantitative	19	143	83	245(82.5)

Qualitative	0	1	0	1(0.3)
Literature	1	23	22	46(15.5)
Mixed	0	2	3	5(1.7)
Doctoral	3	25	24	52(100)
Quantitative	2	22	22	46(88.5)
Qualitative	0	1	1	2(3.8)
Literature	1	1	1	3(3.8)
Mixed	0	1	0	1.(1.9)
Sum	78	52	350	940(100)

4.4. Analysis by study topic

The keywords used to index the papers during the periods used in the study were "technology." "application", "administration," "institution," and "others". After analysis, the most active study field among the theses and journals were technology, application, administration, institution, and others, in this order. This analysis revealed that technology, including development, design, and control of drones, is the most conducted study field.

Table 5: Tendency of study methods by topic fields

Study Field	Journal	Master's	Doctoral	Sum(%)
Technology	196	140	20	356(38.8)
Application	156	85	17	258(27.4)
Administration	124	36	8	168(18)
Institute	100	28	7	135(14.4)
Others	15	8	0	23(2.4)
Sum	591	297	52	940(100)

4.5. Analysis by scource trend

Based on the institutions that granted the study, 76 universities granted the master's degrees to the drone researchers. Korea Aerospace University produced the

most masters, with 21 theses being published. Institutions that granted nine and less were counted as others.
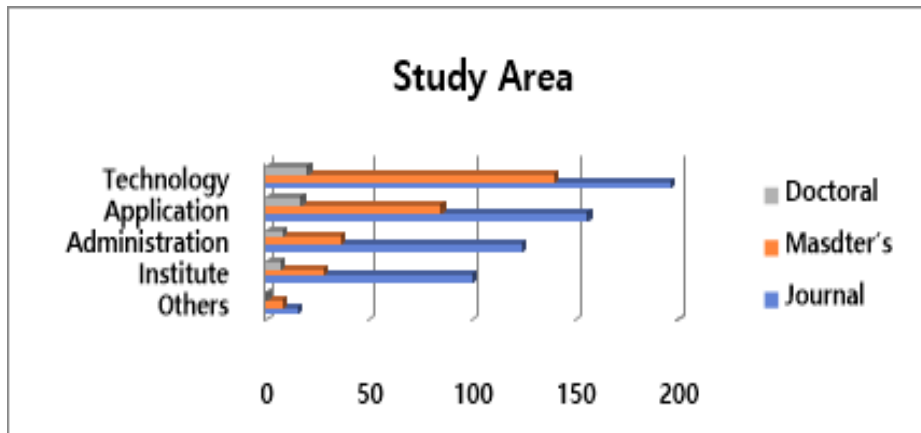

Fig. 4: Tendency of study methods papers by study area (main categories)

For the doctoral theses, 36 universities granted doctoral degree to 52 theses. Kyonggi University, Sejong University, and Hanseo University granted three theses each. Institutions that granted two and less were counted as others. Sejong University produced both master/s and doctoral theses.

Table 6: Analysis of institutions granting master's and doctoral degrees

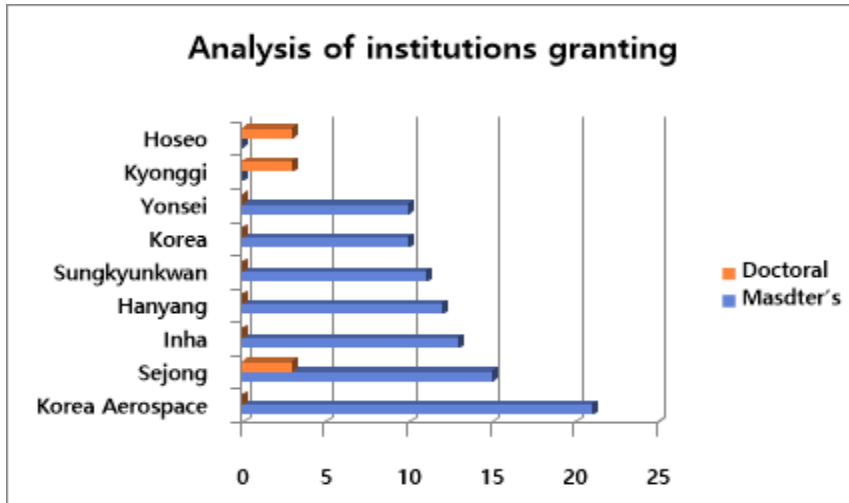| University	Master's	Doctoral	Sum(%)
Korea Aerospace	21	0	21(6)
Sejong	15	3	18(5.2)
Inha	13	0	13(3.7)
Hanyang	12	0	12(3.4)
Sungkyunkwan	11	0	11(3.2)
Korea	10	0	10(2.9)
Yonsei	10	0	10(2.9)
Kyonggi	0	3	3(0.85)
Hoseo	0	3	3(0.85)
Others	205	43	248(71)
Sum	297	52	349(100)

Fig. 5: Analysis of institutions granting master's and doctoral degrees

A total of 233 academic society published 591 journals. KIECS published 17 journals, KIICE published 16 journals, KAIS published 14 journals, and KSAS published 13 journals. KIIT, KSRS, and KASLP pu11blished 12 journals each. KIIS published 11 journals, and the academic societies that published 10 and less journals were counted as others.

Table 7: Analysis of journals publication

Journal	N(%)
Journal of the KIECS	17(2.9)
Journal of the Korea Institute of Information and Communication Engineering	16(2.7)
Journal of the Korea Academia-Industrial cooperation Society	14(2.4)
Journal of the Korean Society for Aeronautical and Space Sciences	13(2.2)
The Journal of the Korean Institute of Information Technology	12(2)
Korea Journal Remote Sensing	12(2)
The Korean Journal of Air & Space Law and Policy	12(2)
Journal of the Korean Institute of Intelligent Systems	11(1.9)
Others	484(81.9)
Sum	591(100)

4.6. Study area trend

Based on the regional trends, 115 of the master's theses were studied in Seoul, 70 in Gyeonggi/Incheon, 54 in Gyeongsang, 31 in Chungcheong, 20 in Jeolla, 6 in

Gangwon, and 1 in Jeju while among the doctor's these, 17 were studied in Seoul, 13 in Gyeonggi/Incheon, 9 in Chungcheong, 7 in Gyeongsang, 5 in Jeolla, and 1 in Gangwon.

For the journals, 165 of them were studied in Seoul, 129 in Chungcheong, 115 in Gyeongsang, 101 in Gyeonggi/Incheon, 63 in Jeolla, 14 in Gangwon, and 4 overseas (tagged as Others). Seoul produced the most theses and journals.

Table 8: Regional trends in theses and journals

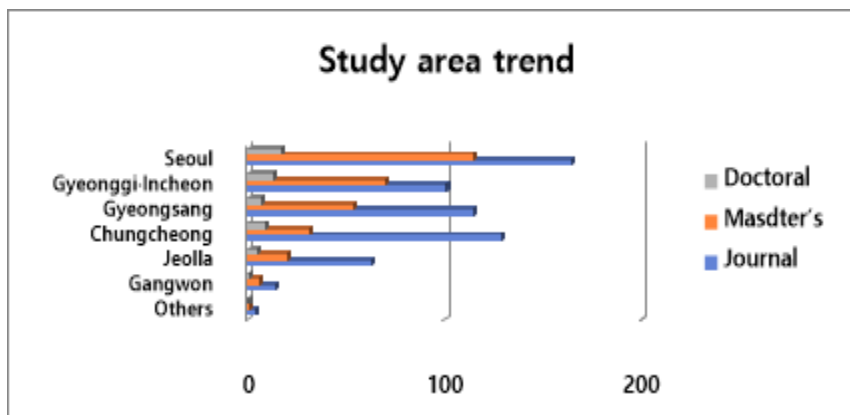| Area	Journal	Master's	Doctoral	Sum(%)
Seoul	165	115	17	297(31.6)
Gyeonggi·Incheon	101	70	13	184(19.6)
Gyeongsang	115	54	7	176(18.7)
Chungcheong	129	31	9	169(18)
Jeolla	63	20	5	88(9.4)
Gangwon	14	6	1	21(2.2)
Others	4	1	0	5(0.5)
Sum	591	297	52	940(100)

Fig. 6: Regional trends in theses and journals

5. Discussion & Conclusion

This study is a trend analysis on master's and doctoral theses and journals on Korean drones. From 2014 to September 2021, 297 master's theses and 52 doctoral theses, a total of 349 theses, and 591 journals were published. There were five time

more male researchers than female researchers. It suggests that male researchers show more interests in drones since these were first applied in the military area and now in construction, firefighting, and logistics where most of the field users are men. As for the study method, researchers preferred to conduct quantitative studies. Drones are machine units and quantitative studies may be appropriate to draw a conclusion from tests and experiments (Seongyoung, 2020)(Seonkyung, 2020)(Chan, 2020)(Jaehyun, 2021). Qualitative studies and literature studies were being conducted actively, along with the quantitative studies. It implies that the drone studies are being versatile as times goes by, in line with the changes and demands of the society.

Regarding the number of theses by the publishing year, there were only three theses in 2014 but since 2019, over 50 theses have been published every year. In the technical area (Yongguk, 2021)(Hakjun, 2020), in the application area (Doopyo at al., 2021)(Hyeseon, 2017), in the administrative area (Heonwon, 2021)(Sehun, 2021), in the institutional area (Byeongseok, 2020)(Oho, 2020), in other areas (Jaeseob at al., 2017)(Hyuntae, 2019), drones are being applied to various areas throughout the society and the interests in drones and its application are increasing.

This can be attributed to the government's policy making, the local government's efforts to foster new industries, and the industrial-academic co-operation to improve core technologies. The statistics of the studies increasing every year demonstrates the researcher's efforts. This study suggests that the government's push for developing drone industry has been implemented in a timely manner. In addition, the sources and area trends seem to be in line with the distribution of the population since Seoul and Gyeonggi are densely populated, having many universities.

Due to COVID-19, this is an age of social-distancing and contact-free lifestyle. It also calls for the needs and desire for safety. The advanced technology of drones and its convergent AI technology innovation provide benefits of convenience, accuracy, and safety in various area. Therefore, there have been growing studies in various fields to improve the quality of human life by using drones. Especially, drones applied to the public field can be a protection against disasters and threats. It is predictable that drones will surely replace human labor while they are entering into the commercial market rapidly. It suggests that it is necessary to conduct constant subsequent studies not just on trend analysis of the entire industry but also the need for technology and the weak points of drones.

In conclusion, the trend analysis of this study proves that drone studies are growing every year. This study will serve as basic data for subsequent studies on drones in practical fields such as drone education system and safety regulations.

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