

Kwon, Hyeseon; Kim, Seongcheol

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## Exploring killer business domains for drones in Korea

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# Exploring killer business domains for drones in Korea

Hyeseon Kwon<sup>a</sup> and Seongcheol Kim<sup>b\*</sup>

<sup>a</sup> *Community Media Foundation, South Korea*

<sup>b</sup> *School of Media and Communications, Korea University, South Korea*

## Abstract

Commercial drone is one of the most promising businesses in IoT industry. However, even if we classify domestic commercial drones market roughly, it still is a broad field since there are diverse domains such as delivery service, media, assessment·business monitoring, agriculture, vehicles, sports·healthcare, and education. In order to promote domestic commercial drone market, this study will try to discover which domain will be the killer. Therefore, this study sheds light on the emerging commercial drone market in Korea. In order to proliferate the commercial drone market in Korea, this study proposes an AHP model for assessing the killer business domain for drones which consists of 9 technology, market, and policy factors. The model was applied to assess and compare the prospect of three drone business domain; media drone, assessment·business monitoring drone, and entertainment drone. By inviting the perception of 39 drone experts, the results showed that assessment·business monitoring drone is the most promising drone in Korea.

Key words: commercial drone, Unmanned Aerial Vehicle(UAV), Analytic Hierarchy Process(AHP)

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\* Corresponding Author

Email address: sunny7087@naver.com (H. Kwon), hiddentrees@korea.ac.kr (S. Kim)

## 1. Introduction

Today, Internet of Things (IoT) is in the midst of rapid transformation and would be the most powerful and inevitable technology in telecommunications industry. 'Unmanned Aerial Vehicles (UAVs)', which are known as 'drones', are one of the most developing and progressive technologies in IoT industry. Recently, the Korean government announced the launch of the post office delivery service of drone. Also, there were opening and closing ceremonies using drones during PyeongChang 2018 Winter Olympic through 5th generation mobile network. They were shooting star drones from Intel, which flew in formation to form the shape of the Olympic rings (Song, 2018). The launch of a delivery service and drone light-up performance displayed through the civil and commercial use of drones, hoping to capture the interest of the public. Although there have been many studies about drones, the main focus was military and public services. Only a few studies have been conducted about commercial drones through communication and social-science perspective.

Commercial drone is one of the most promising businesses in IoT industry. However, even if we classify domestic commercial drones market roughly, it still is a broad field since there are diverse domains such as delivery service, media, assessment·business monitoring, agriculture, vehicles, sports·healthcare, and education. In order to promote domestic commercial drone market, this study will discover which domain will be the killer.

To discover the answer for this research, we will look at first, the definition and main business domains of commercial drones in Korea. Second, we will focus on literature reviews of 'analytic hierarchy process (AHP)' analyses in ICT industries. AHP analysis will then follow up to discover upcoming business field of Korean commercial drones scientifically and systematically. Third, this study will analyze what is the killer domain of the three business domains in Korean commercial drones by using AHP. Forth, this paper will explain practical implications of results for Korean commercial drone industry and market players.

## **2. Theoretical background and methodology**

### **2.1. Definition and main business domains of Drone**

Drones are considered one of Unmanned Aerial Vehicles (UAVs). UAVs cover all vehicles that are flying without a human pilot onboard with capacity controlling the aircraft. This term is used as same as Remotely Piloted Vehicle (RPVs), Remotely Piloted Aircrafts (RPAs), Remotely Operated Aircraft (ROA), Remote Controlled Helicopter (RC-Helicopter), and Unmanned Vehicle Systems (UVS). In short, drones are referred to UAVs or RPAs (Eisenbeiss, 2004; Cavoukian, A, 2012; Mengxiang & Liang Tang, 2017). According to Rouge (2016), 'drone' means "buzz sound of bee". This word is derived from propeller noise that occurs when one flies a drone. The first generally used drone was a 'Queen Bee' biplane and the plane flew without pilot. The initial use of the term 'drone' was derived from this aircraft.

Drones are classified by shapes and sizes, ranging from drone "toys" with four propellers, to "airplane" with one propeller. In this sense, drones are called multi-copters which are propelled by multiple rotors. When the propellers are three, the drone is called a tri-copter, and when they are four and eight, the drone is referred to as a quad-copter and an octo-copter (Rouse, 2016). In addition, the drones can be seen to have added 'mobility' to the 'Internet of things (IoT)' (Motlagh & Arouk, 2016). Motlagh and his colleague (2016) analyzed that drones will play a key role in the IoT vision because of its high mobility. Drones could be used to supply many services such as delivery, farming and rescue operations. Recently, as a representative example of IoT, LG Uplus launched smart aquaculture management service. The drone could be used to manage Database of all the farms (Kim, 2018).

According to the previous studies of drones, this study divided drone business domains into 8 categories; 1) delivery service, 2) media, 3) assessment · business monitoring, 4) agriculture, 5) vehicles, 6) sports · healthcare 7) education · entertainment,

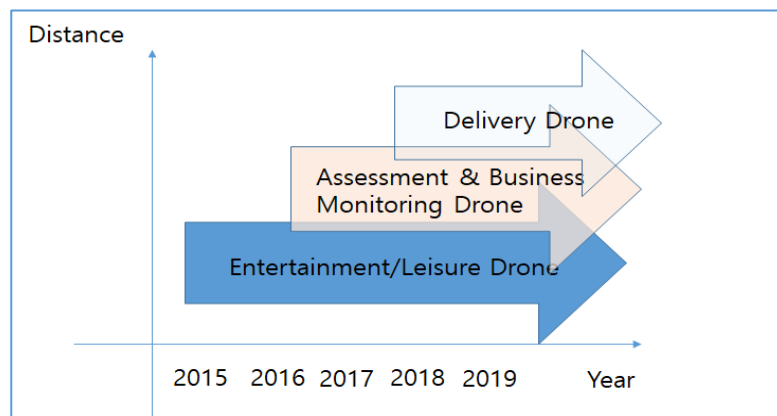
and 8) housing as you can see table.1 (Visser, Dijkshoorn, Van der Veen, & Jurriaans, 2011; Anderson, 2012; Watts, 2012; Paneque-Gálvez, McCall, Napoletano, Wich, & Koh, 2014; Schiavullo, 2015; Williams, 2015; Gabriel, Ramallo, & Cervantes, 2016; Newell, 2017).

**<Table 1 > 8 Main Business Domains of drones**

Purpose	Sub-criteria	Source (author and year)
Delivery service	- Drone for Parcel service of several products - Waiter Drone	Anderson (2012); Williams (2015)
Media	- Broadcasting Drone - News Drone - Interview & Research Drone - PR, Marketing and Advertising drone	Watts et al. (2012); Newell (2017); Williams (2015)
Assessment · Business Monitoring	- Evaluation of Building, Land, and Space - Monitoring of a Construction place	Anderson (2012); Paneque-Gálvez et al (2014); Watts et al. (2012); Williams (2015)
Agriculture	- Sowing & Reaping Drone - Spraying Agricultural Chemical Drone	Anderson (2012); Watts et al. (2012); Williams (2015)
Vehicles	- Navigation Drone - Commuting vehicle & Taxi Drone	Schiavullo (2015)
Sports · Healthcare	- Training - Health Care	Gabriel et al. (2016); Williams (2015)
Education · Entertainment	- Simulation Drone - 3D Game Drone - Concert & Circus Drone	Visser et al. (2011); Williams (2015)
Housing	- Cleaning & Housekeeping	Williams (2015)

Teal Group anticipated that delivery drone, assessment drone, and entertainment drone will be the most promising businesses in the near future among 8 categories. Moreover,

according to Kwon (2017), Korean drone experts have chosen media, assessment·business monitoring, and education·entertainment as the most promising business field in Korean drone market in 10 years. These studies have commonality in two promising business domains for drones which are assessment/business monitoring drone and entertainment drone. Even delivery was one of the most upcoming fields for commercial drone by Teal group's estimation, media was the one last business domain in the basis of Kwon's study. Kwon explained delivery is generally the most promising domain of commercial drones in the United States and China, but not in Korea. Because of many mountains and skyscrapers, drone delivery service in Korea is in the different situations. There are high possibilities of crash or accidents of drone delivery in Korea but also delivery service by men is enough cost-effective at this moment so that there are no more attractive factors to promote drone parcel services (Kwon, 2017).



[Figure 1] Roadmap of commercial Drone Invigoration by Teal Group

## 2.2. AHP model for prioritizing drone business killer domain

Analytic hierarchy process (AHP) is a multi-criteria decision-making approach in a hierarchic structure for complex decision-making process (Saaty, 1990). AHP will be used as a very useful tool to support the most appropriate and strategic decision-making in the field

of drones for civil and commercial purposes. The drones are divided into commercial use and public use. The use of public drones such as military drones are not considered in this paper. There has not been a study about commercial drones by using AHP model yet. This study will adopt an AHP model as a theoretical method.

The AHP can be an appropriate analytical technique for this study for four reasons. First, it is possible to quantify the subjective judgment of each individual, such as experts or ordinary people, who are looking at the drones, and to evaluate them with an objective metric model. Secondly, it is possible to structure and systematize the subdivided and wide. Third, it is possible to prevent errors that may occur when judging the various field of drones through comparison of pairs, and to derive scientific priorities. Finally, it is possible to verify the logical consistency of the analysis results.

### **2.3. Past research**

There has not been a study to analyze a promising commercial drone domain by using AHP model yet. However, there are many meaningful studies in ICT field based on AHP method recently. Neokosmidis and his colleagues explain 5G technology project which is CHARISMA project by a fuzzy Analytical Hierarchy Process (AHP) method. They conducted a survey of several socio-techno-economic factors affecting the market adoption and tried to identify a new telecommunication network (Neokosmidis et al., 2017). In this study, ‘performance’ was the most important criterion among performance, business, economic, acceptance, flexibility, technology. Based on a fuzzy AHP approach, this study identifies important criteria that affect users’ selection of commercial drone services. If we look at the analysis of the sub-criteria related to performance, ‘low latency’ is the most important sub-criterion. ‘New market opportunities’ is the most important sub-criterion of business criterion, alike ‘security and privacy’ of acceptance criterion, ‘SDN’ and ‘NFV’ of regarding criterion, ‘open access’ of flexibility criterion (Neokosmidis et al., 2017).

There is another study about six elements of the business model in Taiwan and 20 critical factors for using AHP method. Chen & Wang (2010) suggested operative strategies

and critical factors of Taiwanese information service firms by literature review. Plus they interviewed senior experts in industry and obtain six major constructions (market segment, strategic alliance, service· implement model, a competition of product, distribution· channel model and revenue efficiency) and 20 criteria (Chen & Wang, 2010).

Shim et al. (2009) considered priorities of primary goals to increase policy efficiency of Green ICT. They presented Green ICT policy making processes concretely and scientifically. To analyze Korean Green ICT policy, they suggested four important domains which are eco-friendliness, technology evolution, economic efficiency, energy efficiency, and stable supply of energy.

Yang et al. (2007) analyzed Business process outsourcing (BPO), which is an advanced type of IT outsourcing, will be the next big wave in information technology services. They explained factors affecting the BPO decision and structures a decision model using the analytic hierarchy process (AHP) method. They suggested three decision factors as 'Expectation', 'Risk', and 'Environment' but also, eight sub-criteria 'Cost savings', 'Focus on core competence', 'Flexibility', 'Information security', 'Loss of control', 'Labour union', 'Morale problem', 'Vendor's service quality'.

## **2.4. Research Question**

The AHP can be an appropriate analytical technique for this study for four reasons. First, it is possible to quantify the subjective judgment of each individual and to evaluate them with an objective metric model. Secondly, it is possible to structure and systematize the subdivided and wide. Third, it is possible to prevent errors that may occur when judging the various field of drones through comparison of pairs, and to derive scientific priorities. Finally, it is possible to verify the logical consistency of the analysis results. In this reasons, this study investigates the following research question.

**RQ : What is the killer business domains for drones in Korea?**



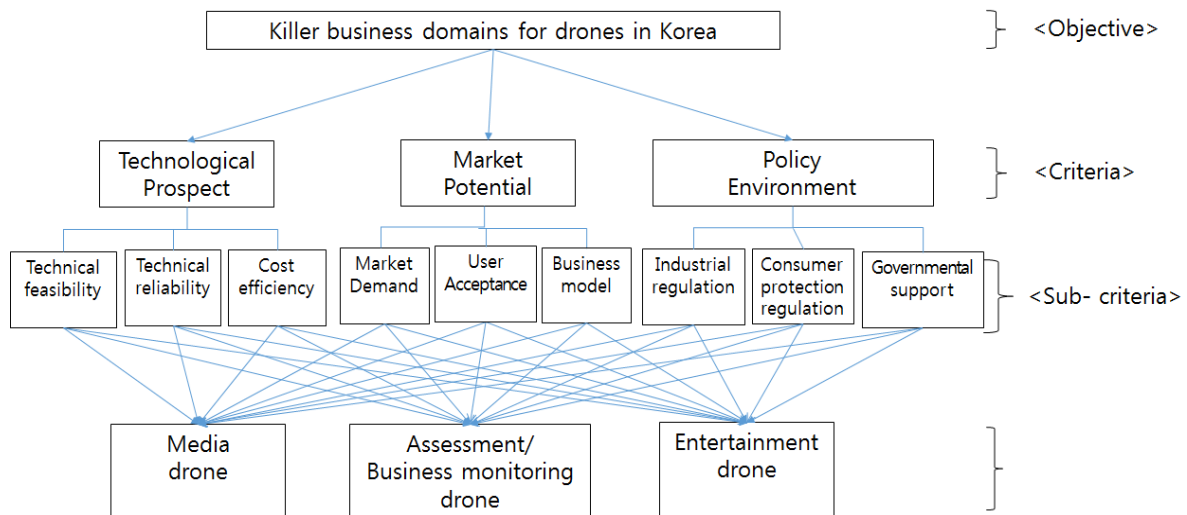
## **2.5. Criteria for assessing killer business domains for drones**

AHP is a multi-criteria decision-making approach in a hierarchic structure for complex decision-making process (Saaty, 1990). AHP is a widely used theoretical modeling technique and this theory was initiated and developed by T. L. Saaty in the early 1970s (Neokosmidis, Rokkas, Parker, Koczian, Walker, Siddiqui & Escalona, 2016; Kim & Kim, 2016; Park, 2017).

The criteria of this AHP model derived from the study of Kim & Kim (2015) mainly but also from the previous interview of drone experts. The first main criterion, technological prospect feasibility, is adopted from the criterion of Kim & Kim (2015)'s paper. This criterion could be more specifically explained by three sub-criteria. Technical feasibility, which is from technological practicality of their study and adjusted to commercial drone ecosystem in Korea. Standardization is not adopted in this study because commercial drone market in Korea has not been promoted yet, so that we decide standardization is not apt to the early market in developing stage (Kim & Kim, 2015).

The second criterion is market potential. It could be divided into three sub-criteria: market demand, user acceptance, and business model. Ecosystem building is also not adopted in this study because commercial drone market in Korea has not been promoted yet. We analyze ecosystem building is not adequate for the early market in developing stage like Korean commercial drone market (Kim & Kim, 2015).

Lastly, the third criterion is policy environment. Regulatory environment in Kim & Kim's study has been adjust to policy environment in this study. This criterion consists of three sub-criteria: industry regulation, consumer protection regulation, and governmental support [Figure 2].



**[Figure 2] AHP model for the evaluation of the killer drone domains in Korea**

To examine the technical prospect of the killer drone domains in Korea, we can evaluate this criterion by following three sub-criteria; technical feasibility, technical reliability, and cost efficiency. (See <table 2>)

**<Table 2> Three sub criteria of technical prospect criterion**

Sub-criteria	Explanation
Technical feasibility	Is this drone domain technically feasible enough?
Technical reliability	Can this drone domain be trusted? Are there any secure problems or privacy issues?
Cost efficiency	Is this drone domain cost-effective in terms of its construction, operation, and management?

Also, to consider the market potential of the killer drone domains in Korea, we can divide three sub-criteria; market demand, user acceptance, and business model. (See <table 3>)

**<Table 3> Three sub criteria of market potential criterion**

Sub-criteria	Explanation
Market demand	Does this drone domain have market demand qualitatively and quantitatively enough?
User acceptance	Is the use of this drone useful and acceptable to a user or massive users?
Business model	Is there any concrete and practical business model for this drone domain?

Lastly, to consider the policy environment of the killer drone domains in Korea, we can suggest three sub-criteria; industry regulation, consumer protection regulation, and governmental support. (See <table 4>)

**<Table 4> Three sub criteria of policy environment criterion**

Sub-criteria	Explanation
Industry regulation	Does present law and regulation related to the commercial drone in Korea prevent this drone domain from promoting and developing?  Is there any movement of related law and policy would be relaxed or modified?
Consumer Protection regulation	Are there any possibilities that uses of these drones are at odds with consumer protection regulations?
Governmental support	Is there any governmental support or promotion for this drone domain?

## **2.6. Data collection**

The proposed AHP model was tested through an expert survey. The respondents consisted of academic experts and industrial professionals of commercial drones and ICT field in Korea. They were carefully selected on the basis of their current interest, job and research experience in drones. The academic and practical backgrounds of the respondents are shown in Table 5.

Out of total 39 respondents, 11 were from private enterprises, who were currently affiliated to a commercial drone corporate or an ICT research department. 6 of them were from government (Ministry of Land, Infrastructure and Transport) and public research institutes (The Korea Transport Institute, Korea legislation research institute and Seoul Digital Foundation) in Korea, whose research areas are ICT policy, drone and other technologies. 4 professors and 2 researchers and 10 graduate students for doctoral course from universities also qualified for this expert survey, considering their current IoT research including drone studies experience as members of government-supported research projects. In addition, a 5 journalist from newspapers (Hangere and Yonhap News) and broadcasting stations (KBS, Peongwha broadcasting station, and YTN), who had recently used drone for report, were invited. 13 of the respondents reported over 5 years of drone field and related research experience.

**<Table 5> Respondents' background as expert**

<b>Affiliation</b>			
Corporate		11	
Government · Public research institute		6	
University		16	
Broadcasting · Newspaper company		5	
Others		1	
<b>Job type</b>		<b>Specialty</b>	
Policy & regulation	8	Broadcasting	7
Research & Develop	5	Telecommunication	4
Planning & Management	4	Internet	12
Research & Education	14	Contents	5

Law	1	Device	3
Journalist & PD	7	IT service · Management	2
		Transportation · Aviation Secure, and others	6
<b>Experience</b>			
Less than 5 years		26	
More than 5 years		13	

## 2.7. Data analysis

The data were analyzed using a technical computing language software, named MatLab, and the computation code was supplied by Kim and Nam (2014).

The survey was conducted in May 2018, via e-mail and in person. Ten cases were found to have Consistency Ratio (CR) below 0.1, while 22 of the 39 answers had CR below 0.2. In studies using AHP method, CR under 0.1 shows us consistency of individual responses. In several studies in social-science area, CR between 0.1 and 0.2 is additionally considered trustfully, because of the difficulties in securing independence between hierarchies and respondents' lack of understanding of AHP method (Saaty, 1980; Yang et al., 2007; Kim & Kim, 2015). Therefore, the 22 answers with CR below 0.2 were finally used for the analysis.

## 3. Results and discussions

### 3.1. Criteria weight

As reported in Table 6, market potential was found to be the most important criterion in the first layer of the model, recording the highest priority weight of .431. Policy environment (.386) was slightly lower than market potential and as followed far away by

technological prospect (.183). In terms of technological prospect criterion, the local score of technical reliability (TR) was found to be the highest (.455), followed by technical feasibility (.323) and cost efficiency (.222). Under the criterion of market potential, business model is the most important criterion in the aspect of its local weight (.469). This sub-criterion was followed by market demand (.285) and user acceptance (.246). In the policy environment criterion, the local score of industrial regulation (.414) is the highest score and second was governmental support (.357 ) and the consumer protection regulation (.229) was the last.

The global weights show us relative importance of each criterion placed in the layer of the AHP criteria. The global weights of 9 sub-criteria are calculated by multiplying the upper-level criteria weights and the local scores (Kim & Kim, 2015). The results showed that the most important criterion in the killer drone domains is business model (.202), followed by industrial regulation (.159). Governmental support (.138) and market demand (.123) were ranked third and fourth. User acceptance (.106) and consumer protection regulation (.088) were the 5th and 6th ranked sub-criteria, followed by technical reliability (.083), technical feasibility (.059), and cost efficiency (.041).

**<Table 6> AHP criteria weight and rank**

Criteria	Weight ( $W_C$ )	Sub-criteria	Local score ( $W_L$ )	Global weight ( $W_C \times W_L$ )	Rank
Technological prospect	.183	Technical feasibility (TF)	.323	.059	8
		Technical reliability (TR)	.455	.083	7
		Cost efficiency (CE)	.222	.041	9
Market Potential	.431	Market Demand (MD)	.285	.123	4
		User Acceptance (UA)	.246	.106	5
		Business Model (BM)	.469	.202	1
Policy Environment	.386	Industrial regulation (IR)	.414	.159	2
		Consumer protection regulation (CP)	.229	.088	6

Governmental support (GS)	.357	.138	3
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### 3.2. Alternative priority

The sum of all the global weights is the total weight of alternatives due to criteria weight ( $\Sigma W_C \times W_L$ ). Looking into Table 8, media drone was found to have advantages in user acceptance (.408) and technical reliability (.391), followed by technical feasibility (.389). The most unfavorable factor for media drone was governmental support (.214). Even though a variation in local weights within an alternative was found, the overall scores of assessment & business drone were higher than those of the other two on average, except technical feasibility of media drone, technical reliability of media drone, and user acceptance of media drone.

In terms of assessment & business drone's local scores, governmental support (.584), industrial regulation (.490) and consumer protection regulation (.489) were the most advantageous aspects while user acceptance (.294) scored the lowest. Entertainment drone marked high local scores in business model (.309), user acceptance (.298), and technical feasibility (.270), however cost efficiency (.198) scored poorly.

<Table 7> Local scores for AHP alternatives

	Media Drone		Assessment & Business monitoring Drone		Entertainment Drone	
	Local score( $W_L$ )	Rank	Local score( $W_L$ )	Rank	Local score( $W_L$ )	Rank
TF	<b>.389</b>	<b>3</b>	.341	8	.270	3
TR	<b>.391</b>	<b>2</b>	<b>.396</b>	<b>7</b>	.214	7
CE	.327	4	<b>.475</b>	<b>4</b>	.198	9
MD	.287	5	<b>.459</b>	<b>5</b>	.254	4
UA	<b>.408</b>	<b>1</b>	.294	9	.298	2

BM	.275	8	<b>.416</b>	<b>6</b>	.309	1
IR	.276	7	<b>.490</b>	<b>2</b>	.235	5
CP	.286	6	<b>.489</b>	<b>3</b>	.225	6
GS	.214	9	<b>.584</b>	<b>1</b>	.203	8

Marked in bold: the highest local score within the criterion

In Table 8, the total weights of the three alternatives are exhibited. The total weight of assessment & business monitoring drone was .446, which is relatively but significantly higher than those of the other two. Media drone (.302) ranked second place, entertainment drone (.252) as the last in priority weight.

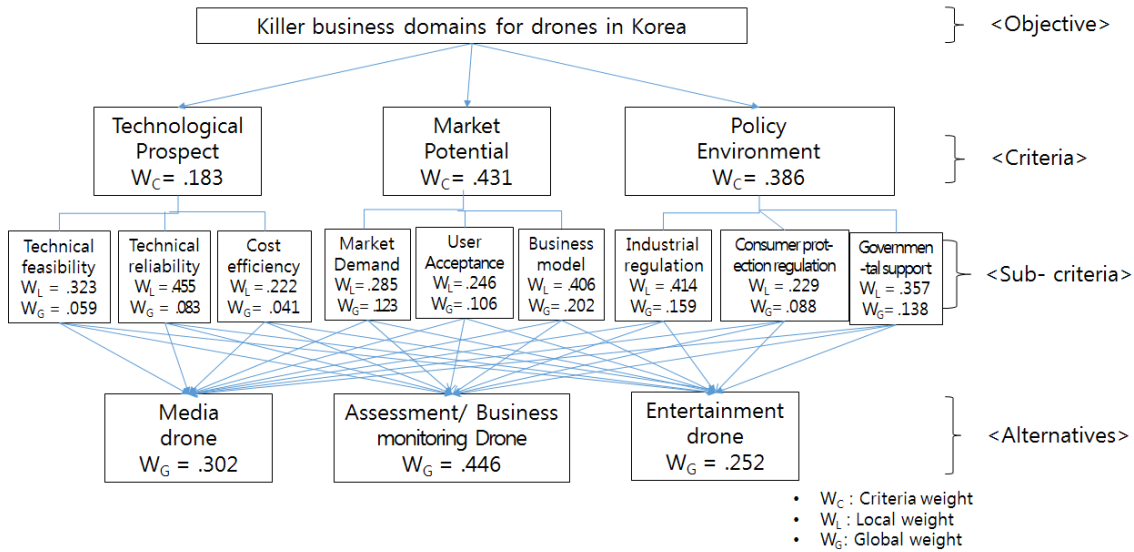
<Table 8> Priorities of AHP alternatives according to criteria

		Media Drone		Assessment & Business monitoring Drone		Entertainment Drone	
	Criteria weight (W <sub>C</sub> )	Global weight (W <sub>C</sub> × W <sub>L</sub> )	Rank	Global weight (W <sub>C</sub> × W <sub>L</sub> )	Rank	Global weight (W <sub>C</sub> × W <sub>L</sub> )	Rank
TF	.059	.023	8	.020	8	.016	8
TR	.083	.033	5	.033	6	.018	7
CE	.041	.013	9	.019	9	.008	9
MD	.123	.035	4	.056	4	.031	4
UA	.106	.043	3	.031	7	.032	3
BM	.202	.056	1	.084	1	.062	1
IR	.159	.044	2	.078	3	.037	2
CP	.088	.025	7	.043	5	.020	6
GS	.138	.029	6	.080	2	.028	5
Total weight		<b>.302</b>		<b>.446</b>		<b>.252</b>	



$(\sum W_C \times W_L)$			
Rank	2	1	3

Figure 3 presents the AHP scores fit in the proposed decision model.



[Figure 3] AHP scores applied in the decision model

### 3.3. Discussions

According to the result of the AHP analysis, the experts perceived business model as most important when assessing the killer drone domains. It means that we need to investigate a diverse business models to promote commercial drone in Korea

Among the three criteria, technological prospect recorded a distinctively low priority weight. This means there's a little difference technology difference between Korea and developing countries of commercial drones. And it also means that we may need to focus on the policy environment and market potential to competitive nation in global market.

Meanwhile, assessment and business monitoring drone was selected by drone experts as the most promising domains with big differences. Drone expert explained there are many upcoming parts in assessment drones such as bridge assessment drones, air condition assessment drones and business monitoring drones for farm and artificial sea farm so that they prospected this drone domain would be certainly the killer drone domains in Korea in 10 years.

#### **4. Conclusion and Implication**

Commercial drone is one of the most promising businesses in IoT industry. However, even if we classify domestic commercial drones market roughly, it still is a broad field since there are diverse domains such as delivery service, media, assessment•business monitoring, agriculture, vehicles, sports•healthcare, and education. In order to promote domestic commercial drone market, this study will try to discover which domain will be the killer. Therefore, this study sheds light on the emerging commercial drone market in Korea.

In order to proliferate the commercial drone market in Korea, this study proposes an AHP model for assessing the killer business domain for drones which consists of 9 technology, market, and policy factors. The model was applied to assess and compare the prospect of three drone business domain; media drone, assessment•business monitoring drone, and entertainment drone.

The AHP analysis showed that assessment and business monitoring drone is the most promising domain in Korea, in the perspective of Korean drone experts, albeit limited in number, due to its strong market potential and technological prospects. Assessment and business monitoring drone is expected to, when commercialized, benefit from business model, government support, and relaxing of industrial regulations, because it is coherently bonded to the policy environmental changes. Assessment and business monitoring drone is also perceived to be technologically realistic and to have a good market potential. Therefore, a commercial drone company, which has a long-term ambition to lead the commercial drone

market in Korea, should be cautious when there are changes in related policies and regulations.

Media drone was perceived to have strength in business model, but cost efficiency. Business model was chosen by all the experts as the first in the AHP criteria weight and rank. All experts suggested that firming and developing business model building in Korean commercial drones is very important factor especially in media drone. While, they answered that they do not care for cost efficiency relatively. It seems that it is not a stage that we care how much money it consumes to develop that business area yet. From this research, we figured out that it is still fostering stage of the commercial drone market before concerning its cost efficiency.

Entertainment, as expected, was also perceived to benefit from building of business model and relaxing of industrial regulation. In fact, in Korea, there are many entertainment drone corporates, people started to open up their eyes to use and to enjoy several toy drones. It means there are several business model in entertainment drones and it begins to succeed to gather the users and to make a fandom for them.

In sum, among the three commercial drone domains, the most promising and realistic domain, namely the killer application, was determined to be assessment and business monitoring drones, due to the strongest and the clearest business model and government support. In the meantime, its inherent limitation cost efficiency also was revealed. In order to minimize such risk, we need to develop higher strategies to compete with cost effective Chinese drones such as DJI.

For policy makers and regulators, these results also imply that government support and consumer protection regulation environment would be a more significant concern especially for assessment and business monitoring drones. Despite its potential market demands, policy environment was perceived as a critical risk that would hamper its innovation and commercialization.

Still, this study has three limitations. First, the empirical analysis is mainly dependent on a limited number of respondents. Even though it attempted to minimize potential bias due to the experts' origin and field experience, the validity of sampling was not confirmed.

Second, all the respondents of the survey were Korean, and they were asked to consider the market and regulatory environment of Korea. Accordingly, the geographical characteristics of Korea would have affected the results. Therefore, the results and implications may be limited only to Korean drone market. Third, this study selectively analyzed only three drone domains. We tried to provide the logic behind the selection of the alternatives, based on a comprehensive literature reviews and drone experts interviews. It is generally analyzed that agriculture drones and delivery drones are also upcoming domains in commercial drones. If the three drone domains are selected differently, the result would be sharply changed.

### **Acknowledgement**

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