J. Internet Comput. Serv.
ISSN 1598-0170 (Print) / ISSN 2287-1136 (Online)
http://www.jics.or.kr

Where and Why? A Novel Approach for Prioritizing Implementation Points of Public CCTVs using Urban Big Data☆

Ji Hye Park[1] Daehwan Kim[2,3] Keon Chul Park[2*]

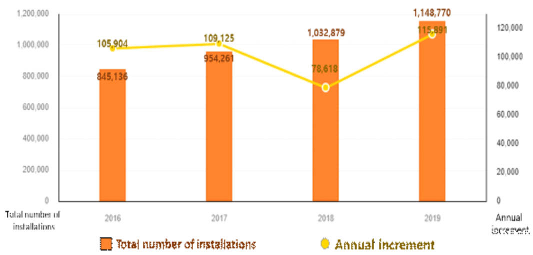
ABSTRACT

Citizens' demand for public CCTVs continues to rise, along with an increase in variouscrimes and social problems in cities. In line with the needs of citizens, the Seoul Metropolitan Government began installing CCTV cameras in 2010, and the number of new installations has increased by over 10% each year. As the large surveillance system represents a substantial budget item for the city, decision-making on location selection should be guided by reasonable standards. The purpose of this study is to improve the existing related models(such as public CCTV priority location analysis manuals) to establish the methodology foranalyzing priority regions ofSeoul-type public CCTVs and propose new mid- to long-term installation goals. Additionally, using the improved methodology, we determine the CCTV priority status of 25 autonomous districts across Seoul and calculate the goals. Through its results, this study suggests improvements to existing models by addressing their limitations, such as the sustainability of input data, the conversion of existing general-purpose models to urban models, and the expansion of basic local government-level models to metropolitan government levels. The results can also be applied to other metropolitan areas and are used by the Seoul Metropolitan Government in its CCTV operation policy

☞ keyword : CCTV; Priority Regions; Public Data; Spatial Analysis; Seoul Metropolitan City

1. Introduction

As social interest in safety increases, citizens'demand for the expansion of the provision of public CCTVs for crime prevention is also increasing. As shown by the results of Office for National Statistics, the number of public CCTVs installed in South Korea increased by about 100,000 per year, from 850,000 in 2016 to 1.15 million as of 2019. Considering that about 11,000 units were installed in 2010, which is about 17% of the total in 2019, we can see that more than 10% more public CCTVs have been newly installed every year compared with the previous year.



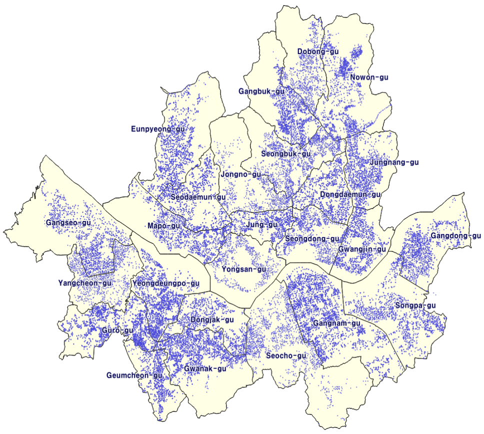
(Figure 1) Trends in the Number of CCTVs Installed by Public Institutions in South Korea (Office for National Statistics, 2018)

Until the 2010s, when selecting new installation sites for public CCTVs, there were no systematic standards or manuals[1]. Thus, the sites were selected mainly in areas where there were many public requests for installation. However, from an objective point of view, the fact that there have been many requests (or complaints about the

1 AI/Big Data Team, Seoul Digital Foundation, Seoul, 03909, South Korea
2 Urban Computing & Innovation Lab, Advanced Institute of Convergence Technology(AICT), Suwon, 16229, South Korea
3 Dept. of Civil and Environmental Engineering, Seoul National University, Seoul, 08826, South Korea
* Corresponding author (parkkc07@snu.ac.kr)
[Received 17 July 2023, Reviewed 27 July 2023, Accepted 13 September 2023]
☆ This work is supported by the Korea Agency for Infrastructure Technology Advancement(KAIA) grant funded by the Ministry of Land, Infrastructure and Transport(Grant RS-2023-00260987).
☆ This work is developed result of paper presented at The 18th Asia Pacific International Conference on Information Science and Technology (APIC-IST 2023), organized by the Korean Society for Internet Information (KSII).

http://dx.doi.org/10.7472/jksii.2023.24.5.97

nonavailability of CCTVs) does not necessarily mean that CCTVs are urgently needed in that area. For example, many complaints may come from one person or may be based on subjective inconveniences and complaints. Additionally, a single location includes at least three to four cameras, and considering such things as electrical wiring, additional construction, and subsequent operations and maintenance, each installation location costs about 20-30 million won [2]. Considering the impact on the budget, the reality is that public CCTVs cannot be installed at all demand points. Therefore, an objective and reasonable selection process for new public CCTV installation regions has to be applied, rather than selecting locations through an unstructured and subjective method.



(Figure 2) Public CCTV Distribution of Seoul in 2019(Analysis Result by Researcher Using GIS)

In this context, this study aims to review existing relevant studies and establish a methodology for analyzing Seoul-type public CCTV priority regions to overcome the limitations of existing models. The results derived by applying real data throughout Seoul are empirically shown, while new mid-to-long-term installation goals of Seoul are presented.

2. Related Work

This section discusses the international and domestic research in Korea related to public CCTVs.

2.1 International Research

First, international research has mainly focused on identifying the crime prevention effects of CCTV. Harris et al. [3] studied the cost-effectiveness of CCTVs and the direction of the introduction of systems, including personal privacy issues, amid the growing use of CCTVs in the 1990s for crime prevention in the United States and Britain. Welsh and Farrington [4] found that CCTV-equipped areas saw crime reduction of more than 20% compared with control groups. It was most effective in reducing crime in parking lots, especially when coupled with improved street lighting and when focused on vehicle-related crime.

In addition, there are many studies on the factors that affect the degree of effectiveness of CCTV beyond the simple crime prevention effect. This trend is also confirmed by research conducted by Welsh and Farrington [5].They examined 93 studies focused on the public domain and crime reduction effects as a result of being monitored through CCTVs by means of a meta-analysis. Forty-four studies determined that the installation of CCTVs is sufficiently effective in reducing crime. In relatively recent years, research has focused on identifying the factors affecting crime reduction due to CCTV usage, rather than simply the effect of overall crime reduction due to CCTV. For example, Gil et al. [6] showed that unlike the public's positive perception of CCTV installation and operation in the public domain, the strength of positivity was relatively low in neighborhoods with housing, where the installation areas are private. Also, Piza [7] measured the inhibitory effectiveness of CCTV on violent crime, vehicle theft, and in-vehicle theft by comparing control and experimental groups through propensity score matching. This research confirmed that in the appropriateness of CCTV in reducing crimes, it has a deterrent effect only on vehicle theft crimes. Additionally, Piza et al. [8] recently systematically reviewed 40 years of prior work through meta-analysis. The summarized result of research was that the installation of CCTVs was significantly related to crime reduction, but the effectiveness varies depending on the installation location, with residential areas showing significant crime reduction effects. They also examined the impacts of CCTV deployed with combinations of several other interventions rather than just CCTV alone.

2.2 Domestic Research

Meanwhile, in Korea, since the 2010s, the installation of public CCTVs has been spreading rapidly, relying on CCTV location analysis based on space and location data. The main trend is to select the optimal location to prevent crime.

Kim [9] proposed a method for calculating the risk points for each building by utilizing the location and property of the road and the building's location and property to improve location analysis. Previously, crime-related information was provided only in administrative units; thus, the details of vulnerable areas could not be identified. In particular, Jang et al. [10] turned away from CCTV location analysis based on crime occurrence data by administrative dong (district) unit; they proposed a method to improve CCTV location analysis by combining the installation locations for crime prevention with address information of crime occurrence points and basic spatial data of case areas. Lee and Kim [11] proposed the selection of locations for Ansan City, one of the local governmental areas, by applying floating population data. Park and Kim [12] demonstrated how to analyze CCTV locations using crime statistics with no address details. Identifying vulnerable areas using dangerous road extraction, building use, building type, income distribution, population distribution, and existing CCTV concentration areas was highly accurate compared with the crime-ridden areas presented in the national safety map.

Meanwhile, Park and Lee [13] proposed an optimal location selection method for CCTVs, considering factors for three-dimensional filming, including the size and focal distance of the "Charge Coupled Device" that affects the angle of view of cameras, the height of installation related to the filming range, and the angle. Moon [14] presented the factors and the importance of each factor as reasonable criteria for the location selection for CCTVs for crime prevention through the Analytic Hierarchy Process to relevant experts such as university professors, researchers, police officers, and government officials. Kim and Park [15] proposed a location analysis model in a study conducted by Dongjak-gu in Seoul as an example, including the location of crime, 112 reporting locations, CCTV installation requests, and the locations of CCTV installed, as well as the social, economic, and environmental characteristics of the area (population, education level, aging index, wage, public land price, and industry). Also, Kim et al. [16] proposed a method for estimating crime vulnerabilities that can be utilized for analyzing CCTV locations by combining road and building property information and floating population data, considering the recent domestic situation in which it is difficult to get crime location data. Additionally, Lee [17] proposed an optimal location model that covers the maximum demand points for each hour by developing a space optimization model that maximizes the city's three-dimensional geometrical characteristics and the maximum monitoring distance of CCTVs by viewing Daegu Metropolitan City's potential demand for public CCTVs using telecommunication data as an example.

In terms of location analysis conducted at the government level, the Ministry of Public Administration and Security, South Korea, developed in 2016and distributed in 2017 standardized public CCTV priority location analysis manuals to prevent overlapping and inefficiency of similar projects among agencies. This model supports existing decision-making systems that relied on civil complaints or personnel experience and intuition to be reasonable. The primary data used in the model are CCTV installation information, crime occurrence address, store business data, floating population data, resident population data, housing type data, and registered foreign address. Based on those data, two sub-indexes and three weights are calculated, and the final priority index [PI] by grid cell is derived [18]. Since its development and distribution, this model has been frequently used by local governments. Sung et al. [19] applied the model to Gimhae City, a local government region, to verify its performance. The index was high in blind spots where the actual number of CCTV installations was insufficient, and the validity and suitability of the model were shown to be quite consistent with the areas where many complaints were filed. In addition to this, Gyeonggi Provincial Government and Daegu Metropolitan City also used public and private data to extract the analyzed points through intersections and derive and utilize the final priority installation points such as crime-related indices, existing CCTV surveillance radius, and weights [20, 21].

However, prior research was limited in that it did not cover the characteristics of the Seoul Metropolitan

Governmental region, big data of urban sustainability, and policy usability. Therefore, this study proposes a methodology to improve these three aspects and proposes a new number of mid- and long-term CCTV installation targets achieved early by the Seoul Metropolitan Government through the developed methodology. We also show the results of the application throughout Seoul as an example.

3. Research Data and Methodology

3.1 Research Data

A total of 11 types of data were used, of which 9 were public data such as “Seoul Open Data Plaza (data.seoul.go.kr)” and “Official South Korea Government Data Portal (data.go.kr).” The location of the financial establishments was collected by crawling, and the existing CCTV installation locations were provided directly by 25 autonomous districts in Seoul. Four types of data were replaced by new ones after considering the sustainability of the data compared with the model of the Ministry of Public Administration and Security.

First, as the supply and demand of address data from the National Police Agency for registered foreigners were previously assumed, but it is practically impossible to secure them, this study uses the number of cases of five major crimes and registered foreigners in the district units (Gu, Dong). Next, for the financial sector, data on which are not provided by the Commercial store data on data.go.kr, the method of collecting data into Python using an open API was adopted. In the case of floating population data, it was difficult to secure sustainability data because it needed to be purchased annually from private telecommunication companies; however, in the case of the Seoul Metropolitan Government, Living Population Data, which can be secured annually through business agreements with KT, were utilized. For detailed equations, see Section 3.3, and for related dataset, see Table 1.

(Table 1) List of Dataset

Collected Data	Level
Seoul Metropolitan Area Grid (map.ngii.go.kr, 2020. 4.)	Grid Cell (100m*100 m)
Existing CCTV installation locations (Each district of Seoul, 2020. 4.)	Latitude, Longitude
Status of the five major crimes (data.seoul.go.kr, 2019. 10.)	Districts (Gu)
Commercial store data(data.go.kr, 2019. 12.)	Address
Location of financial establishment (Crawling, 2020. 5.)	Latitude, Longitude
Living population data* *Population existing in a specific area at a unit time(data.seoul.go.kr, 2020. 1.)	Districts (Dong)
Resident registration population (2020. 4.)	Grid Cell (100 m*100m)
Building register headings (cloud.eais.go.kr, 2020. 3.)	Address
Number of registered foreigners (data.seoul.go.kr, 2020. 1st quarter.)	Districts (Dong)
Number of productive populations (map.ngii.go.kr, 2020. 4.)	Grid Cell (100m*100m)
National Building Integration Information (Ministry of Land, Infrastructure, and Transport, South Korea, 2020. 9.)	Building

Meanwhile, five types of data levels are utilized, grid cell (100m*100m), latitude and longitude, districts (Gu and Dong), and addresses, among which the data level is converted to Geo-code and longitude. Even if the data level is different, the standard analysis unit is grid cell level, and the final PI and Index Classification are also calculated by grid cell. However, unlike the preceding study [18], this study includes all 25 autonomous districts of Seoul Metropolitan City, and since the analysis unit is a grid cell rather than a spot at the intersection, there is an issue that there exists a cell with overlapping jurisdictions between districts (Gu). In this case, the average value of N for each Gu was used for the data values calculated for each cell.

3.2 Research Process

All the analytical tools used are open source. R was used for pre-processing data, such as merging existing CCTV installation data by autonomous region; Python was used for data collection; and QGIS was used for spatial analysis. The open API provided by Kakao (developers.kakao.com) and Python was used for Geo-coding, which converts addresses into latitude and longitude.

The analysis was carried out in the following six steps. First, the original data were secured and refined for analysis. The grid cells, which were not subject to analysis, were excluded at this stage. In the case of the Ministry of Public Administration and Security model, the minimum number of people per cell was set as the minimum number of people,but in this study the number was raised to 10 considering the metropolitan characteristics of Seoul. Further, for the models in the cities of Gyeonggi-do and Daegu, the analysis target was set as intersection spot rather than grid cell; however, this study was focused not only on location analysis but also on identifying the overall CCTV installation levels of each Seoul Metropolitan Government district and calculating the mid- to long- term number of installation targets. Hence, each grid cell was analyzed as a unit of analysis considered for installation in addition to intersections. However, exceptions such as large-scale apartment complexes and university sites where the area of private land exceeded 90% for each cell or require other treatment were excluded from the analysis.

Next, to calculate the CCTV Monitoring Vulnerability Index (MVI), monitoring coverage was set based on the location of installed CCTV cameras; the coverage area of the device was removed from the corresponding grid cells. Three factors－"Occurrence Factor," "Environmental Factor," and "Floating Population Factor"－were calculated and added together for the Crime Vulnerability Index (CVI). Afterward, the three weights were calculated to reflect the other characteristics of each grid cell. The final PI for each grid cell was calculated by adding the CCTV MVI and the CVI and multiplying the weights.

Finally, the PI was graded into five levels to derive the status of Seoul Metropolitan Government districts and utilized to set standards for mid-to-long-term CCTV installation goals.

3.3 Model

3.3.1 CCTV Monitoring Vulnerability Index (MVI)

MVI evaluates the vulnerability of CCTV coverage by grid cell. Each cell is 100m wide and vertical, so the area is 10,000. The area monitored by the CCTVwas determined, as well as the proportion of the monitoring area from each cell. The surveillance radius was set at 50 m and 360˚, which are the average characteristics of the CCTV status data provided. Thus, 10 times the ratio of the area out of reach of CCTV in one cell yields a CVI with a value of at least 0 to a maximum of 10 points.

3.3.2 Crime Vulnerability Index (CVI)

The CVI consists of three factors. First, the Occurrence Factor is calculated: the number of major crimes in each of the 25 autonomous Seoul Metropolitan Government districts is weighted according to crime type and then added together. Next, the weights for each type of crime are determined as follows: five points for murder, four points for robbery, four points for rape, coercion, and molestation, and three points for theft and violence, referring to the existing model. Next, 2.75 points are awarded for the sum of the number of crimes in the corresponding Gu, 2.25 points for the lower 5th, and 2.5 points for each Gu between 6th and 19th places. Finally, each grid cell belonging to each Gu is given a value. Meanwhile, the influence of the CVI was reduced in accordance with the utilization of Gu level data, and the value range was adjusted from 1 to 5 points to 2.25 to 2.75.

Environmental Factor (EF) is the total number of stores present in each cell multiplied by 5 in the proportion of entertainment, lodging, and finance sectors. However, for cells with fewer than five stores, EF can be overcalculated, so 0 points are given as EF.

The Floating Population Factor gives points for each percentile segment based on the floating population of crime-prone females at night (6-11 PM) and during late-night (11 PM to 6 AM). If the top 20% of the floating population are included, three points will be awarded, for 20-40%, 2.75 points will be given, for 40-60%, 2.5 points will be given, for 60-80%, 2.25 points will be given, and for

80-100%, 2 points will be given. Because Dong unit data are utilized, the factor influence is reduced compared with the previous one, and the value range of 1-5 is adjusted to 2-3.

3.3.3 Weight

Individual characteristics of each cell are reflected through three types of weights. The Vulnerable Female Weight will be 1.095 (9.5%) if the proportion of the female population from elementary school students to those in their 30s is larger than the average in Seoul. The Detached House Weight will be 1.041 (4.1%) if the proportion of detached houses is larger than the average in Seoul. Foreigner Weight will be 1.014 (1.4%) if the proportion of registered foreigners in the working-age population is larger than the average of Seoul. The value byweight type was that used in Jang et al. [10]

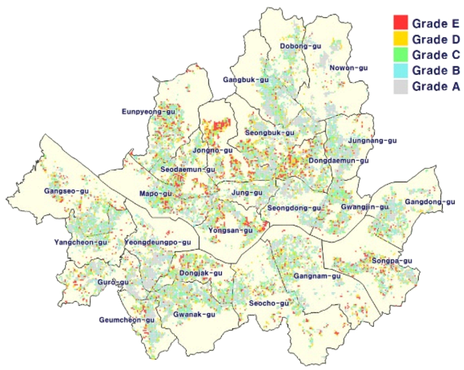
3.3.4 Priority Index (PI) and Index Classification

The final PI is derived using each of the factors calculated in the preceding processes. According to the derived PI points, five grade levels, from E to A, are assigned by grid cell (Table 2). The higher the PI points, the lower the grade and the higher the need for CCTV installation. Grade E refers to areas where better monitoring coverage is needed and crime vulnerability is high, and thus CCTV installation is most urgent. Grade D is an area that needs attention to both monitoring and crime, and Grade C is an area that needs more attention to one of the two factors, so the CCTV installation is required at a normal level. Grade B is an area where monitoring coverage or crime levels are good, and Grade A is the least urgent area to install CCTVs. Thus, eliminating the area of Grade E (cell) is the standard value for the number of CCTV installation targets in Seoul.

(Table 2) Priority Index(PI) Classification

Priority Index Point	Grade
Greater than 15	E
Greater than 13 and less than or equal to 15	D
Greater than 11 and less than or equal to 13	C
Greater than 9 and less than or equal to 11	B
Less than or equal to 9	A

4. Result



(Figure 3) Priority Grade Distribution in Seoul

The methodology presented in Section 3 was applied to 25 autonomous Metropolitan districts of Seoul to derive the CCTV priority regions and mid- to long-term targets for installation. Of the 19,129 grid cells analyzed, 10.6% (2,036 cells) are Grade E (Table 3), indicating an urgent need to install CCTVs in these districts. Of the total number of Grade E cells (2,127 cells), Jongno-gu was 11.2%, followed by Dongdaemun-gu (7.4%), Eunpyeong-gu (7.1%), Seodaemun-gu (6.7%), and Yongsan-gu (6.1%).

(Table 3) Number and ratio of cells by grade

Grade	Num. of Cells	Percent of Total
E	2,036	10.6%
D	2,479	13.0%
C	3,066	16.0%
B	3,748	19.6%
A	7,800	40.8%
Total	19,129	100.0%

(Table 4) Results of the number of grades by district

District (Gu)	Total Cells	Num of Cells by Grade				
		E	D	C	B	A
Jongno	973	238	194	150	137	254
Dongdaemun	859	157	154	140	175	233
Eunpyeong	918	152	138	170	211	247
Seodaemun	870	142	145	165	170	248
Yongsan	736	129	107	136	127	237
Songpa	862	128	140	146	175	273
Mapo	859	119	96	159	200	285
Seongbuk	1,186	110	167	167	199	543
Seocho	876	106	141	165	177	287
Dongjak	814	105	133	168	154	254
Gangseo	859	99	141	145	177	297
Gangnam	1,045	85	136	172	199	453
Gwangjin	781	80	95	148	175	283
Guro	737	77	80	93	122	365
Gwanak	1,056	61	114	191	223	467
Yeongdeungpo	756	55	59	71	136	435
Geumcheon	527	52	70	74	98	233
Gangdong	708	43	73	115	158	319
Yangcheon	640	41	75	109	151	264
Jungnang	810	39	71	113	171	416
Jung	504	26	70	66	96	246
Seongdong	643	23	54	75	130	361
Gangbuk	816	22	76	116	167	435
Nowon	486	21	37	43	65	320
Dobong	584	17	59	110	109	289
Total	19,905	2,127	2,625	3,207	3,902	8,044
Average	796	85	105	128	156	322

The number of cells is different for each borough, with Grade E ratios ranging from 2.7% to 24.5%. The top five grade E ratios by autonomous district (see Table 5), from the highest to the lowest (range 24.5-16.3%), were Jongno-gu, Dongdaemun-gu, Yongsan-gu, Eunpyeong-gu, and Seodaemun-gu. From the lowest to the highest, the bottom five boroughs were Gangbuk-gu, Dobong-gu, Seongdong-gu, Nowon-gu, and Jungnang-gu.

(Table 5) Results of the ratio of grades by district

District (Gu)	Num of Cells by Grade				
	E	D	C	B	A
Jongno	24.5%	19.9%	15.4%	14.1%	26.1%
Dongdaemun	18.3%	17.9%	16.3%	20.4%	27.1%
Eunpyeong	16.6%	15.0%	18.5%	23.0%	26.9%
Seodaemun	16.3%	16.7%	19.0%	19.5%	28.5%
Yongsan	17.5%	14.5%	18.5%	17.3%	32.2%
Songpa	14.8%	16.2%	16.9%	20.3%	31.7%
Mapo	13.9%	11.2%	18.5%	23.3%	33.2%
Seongbuk	9.3%	14.1%	14.1%	16.8%	45.8%
Seocho	12.1%	16.1%	18.8%	20.2%	32.8%
Dongjak	12.9%	16.3%	20.6%	18.9%	31.2%
Gangseo	11.5%	16.4%	16.9%	20.6%	34.6%
Gangnam	8.1%	13.0%	16.5%	19.0%	43.3%
Gwangjin	10.2%	12.2%	19.0%	22.4%	36.2%
Guro	10.4%	10.9%	12.6%	16.6%	49.5%
Gwanak	5.8%	10.8%	18.1%	21.1%	44.2%
Yeongdeungpo	7.3%	7.8%	9.4%	18.0%	57.5%
Geumcheon	9.9%	13.3%	14.0%	18.6%	44.2%
Gangdong	6.1%	10.3%	16.2%	22.3%	45.1%
Yangcheon	6.4%	11.7%	17.0%	23.6%	41.3%
Jungnang	4.8%	8.8%	14.0%	21.1%	51.4%
Jung	5.2%	13.9%	13.1%	19.0%	48.8%
Seongdong	3.6%	8.4%	11.7%	20.2%	56.1%
Nowon	4.3%	7.6%	8.8%	13.4%	65.8%
Dobong	2.9%	10.1%	18.8%	18.7%	49.5%
Gangbuk	2.7%	9.3%	14.2%	20.5%	53.3%
Average	10.2%	12.9%	15.9%	19.6%	41.5%

5. Conclusion

This study produced a proposed systematic and objective method for analyzing CCTV priority regions and a method for calculating the number of mid-to-long-term installation goals from the perspective of the Seoul Metropolitan Government. Additionally, actual data were applied to 25 autonomous districts in Seoul according to the methodology developed, and the results of the analysis were shown as examples. The proportion of Grade E regions, where there is an urgent need to install CCTVs, is 10.6%, and the number of mid- to long-term installation targets is 2,036. We have interviewed the relevant departments of the Seoul Metropolitan Government several times regarding the developed model and determined the results are reasonable and useful for practical use.

This study overcomes the limitations of existing models by taking into account the view of the Seoul Metropolitan Government, the sustainability of urban big data, and policy-utilization aspects. It also provides as a basis for the Seoul Metropolitan Government's mid-to-long-term goals for installing CCTVs and the differential allocation of subsidies to autonomous districts.

However, this study requires some supplementation to increase the discrimination power and accuracy of the PI and grade calculated by cell. First, we need to update the information on the existing CCTVs. The data will need to be supplemented to correct the installation angle and coverage. Next, the sustainability of the model and data should be considered, but the acquisition of possible address or cell-unit data should be sought. Additionally, the components of the model are not fixed−they should be modified as society changes; thus, the model should be periodically upgraded to reflect this reality.

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◐ 저 자 소 개 ◑

박 지 혜(Ji Hye Park)
2018년 경희대학교 대학원 경영학과 박사(석박사통합과정)
2018년~2020년 충북연구원 미래기획센터 전문위원
2021년~현재 서울디지털재단 AI·빅데이터팀 책임
관심분야 : 재난안전, 공간분석, 스마트시티, 사물인터넷, 최적입지
E-mail : jhpark@sdf.seoul.kr

김 대 환(Daehwan Kim)
2020년 서울대학교 건설환경공학부 공학석사
2020년~현재 서울대학교 건설환경공학부 박사과정
2020년~현재 차세대융합기술연구원 연구원
2022년 서울시 서울데이터펠로우쉽사업 펠로우 대표
관심분야 : 도시공학, 데이터사이언스, 어반컴퓨팅, 스마트시티
E-mail : dhbit@snu.ac.kr

박 건 철(Keon Chul Park)
2011년 연세대학교 대학원 정보시스템학과 석사
2015년 연세대학교 대학원 정보시스템학과 박사
2015년~2016년 성균관대학교 인터렉션사이언스학과 박사후 연구원(Post-doc)
2016년~2021년 서울디지털재단 정책연구팀장, 데이터혁신팀장
2021년~현재 차세대융합기술연구원 도시데이터혁신연구실 실장(선임연구원)
관심분야 : 도시정보학(Urban Computing), 인공지능, 빅데이터
E-mail : parkkc07@snu.ac.kr