Project Report of Master of Engineering

Deriving Smart City ESG Performance from Infrastructure, ICT and Service sectors

Infrastructure, ICT, Service 부문을 통한 스마트시티 ESG 성과도출 연구

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Graduate School of Engineering Practice
Seoul National University
Department of Engineering Practice

SeungMin Lee

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Changwoo Park
KunSoo Park

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Graduate School of Engineering Practice
Seoul National University
Department of Engineering Practice

SeungMin Lee

Confirming the master's Project Report written by
SeungMin Lee
February 2023

Chair	Yoonmo Koo
Examiner	Young Hoon Kwak
Examiner	Changwoo Park
Examiner	Kun Soo Park

Abstract

As population density increases due to urbanization, a comprehensive sustainability strategy aimed at creating optimal conditions for people living in cities is needed. Smart cities have emerged to solve the challenges of urbanization by integrating information and communication technology (ICT) and physical infrastructure that provide various services to citizens. As more smart cities are built around the world, it is important to understand the environment, social, and governance (ESG) performance of smart cities that can help finance, develop, and sustain smart cities. This is because the ESG of companies participating in the smart city will have an essential influence on the continuous operation of the smart city while assuming that the recent smart city is developed by private companies rather than by public institutions or the government. ESG is a quantitative and effective tool to prove a company's sustainability. However, there are no studies on specific procedures, indicators or guidelines for reviewing or understanding the ESG level of smart cities. To solve this problem, this study examined a comprehensive overview of the current ESG level of smart cities by utilizing ESG score data of infrastructure, ICT, and service sectors that play an important role in smart cities. Then, multiple linear regression analysis was performed using the ESG scores of the following three categories to present a basic

model that can infer the ESG level of smart cities. This study is significant in that it attempted to develop a basic model that can infer the ESG level of a smart city that did not exist before. In addition, according to previous studies, since companies try to strengthen competitiveness by benchmarking ESG policies or scores of companies that are influential or recognized as similar companies, the study can motivate companies that wish to participate in smart cities to achieve sustainability management by comparing and analyzing the ESG levels of companies participating in smart cities.

Keywords : Smart city, Sustainable city, Environment, Social and Governance (ESG), Infrastructure, Information and Communications Technology (ICT), Service, Multiple linear regression

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Chapter 1

Introduction

1.1 Background

By 2050, 70% of the world's population is expected to be concentrated in cities, which will likely increase resource consumption and greenhouse gas emissions due to urbanization [2]. Figure 1 shows that the population has been increasingly concentrated in cities since 2010. According to the graph, the population living in the city is 2.2 times higher than the population living in Rural in 2050. As population density increases, the pressure on resources (energy, water, and sanitation) and the need for high-quality public services grows [3]. Along with resource and environmental issues, a comprehensive sustainability strategy aimed at creating optimal conditions for people living in cities is needed to improve the quality of urban life.

Because urbanization with concentrated population does not only have positive aspects, smart cities have been highlighted globally as a counter-measure against its negative aspects [4]. A smart city is a city that is planned with the goal of providing lifestyles and convenience for citizens, centering on sustainable practices and environmentally conscious green companies [3]. Environmental sustainability is also an essential goal of smart cities [5].

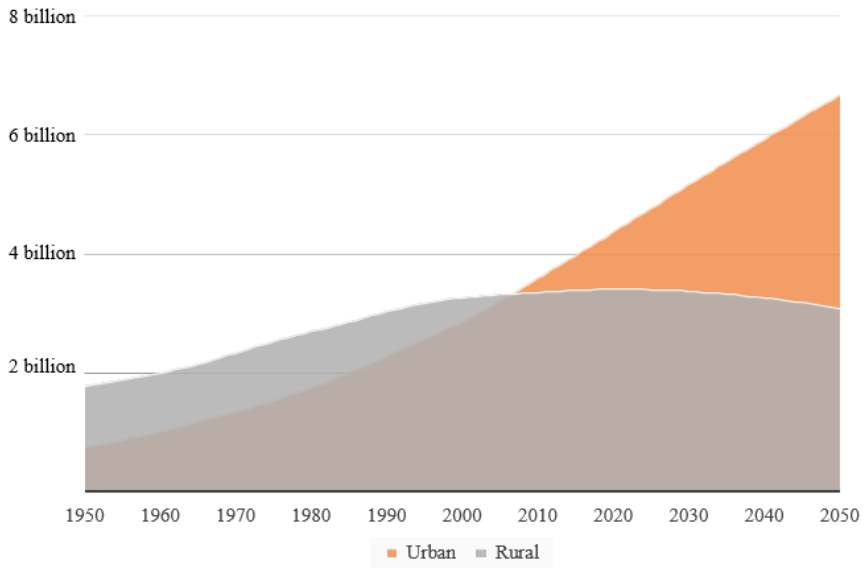

Figure 1: World's urban and rural population (Data source: [1])

Sustainability goals can be achieved with the help of "smartness" which has increased the popularity of the smart city concept [6].

A smart city provides a service platform for citizens and cities as a smart city composed of Infrastructure, ICT and Services connects physical locations to cyberspace [7]. The central axis for creating a sustainable smart city is the Internet of Things (IoT), and by combining information and communication technologies, the quality of life can be elevated by maximizing the city's services that monitor and integrate all the conditions of major infrastructure [3]. Following the review of previous studies that define smart cities, we specified the industrial sectors that play a pivotal role in smart cities as Infrastructure, ICT, and Service.

These smart cities ultimately aim to create a sustainable city, including the quality of life and environment for citizens. Because the smart city contains the concept of "sustainable city," the ESG concept, which is a sustainable management activity, is ultimately needed.

ESG is not only necessary to create smart cities, but it is a necessary measure to create a sustainable future for all to thrive. Although there is no definitive and specific method to build a smart city, ESG that quantitatively shows the negative and positive impacts of businesses on society is vital to provide a better quality of life and a cleaner environment.

In short, sustainability and smart city are interrelated, and the ESG score can serve as a key indicator in realizing a sustainable smart city [8]. If so, can the ESG level of the current smart city be measured? Our research began with this question. Previous studies mainly looked at the ESG scores of companies and analyzed the correlation with financial performance or evaluated the companies' level of effort for sustainability [9], [10], [11], [12].

Currently, the ESG level of smart cities cannot be determined, and studies on evaluation standards or guidelines are extremely rare. We attempted to analyze the company's ESG data in the infrastructure, ICT, and Service sectors that play a critical role in the smart city, examine the ESG level of the smart city, and present a basic model formula that can infer the ESG

score of the smart city in the future. Multiple linear regression analysis was used for deriving the model formula.

Before collecting corporate data from three industrial sectors, this study first identified the industries belonging to the three industrial sectors as shown in Figure 2 using the industry classification criteria of the Sustainability Accounting Standards Board (SASB) [13]. SASB is an ESG guideline framework that sets the standards for companies to provide financially important sustainability information to investors. Generally, since corporate reports, investors, and researchers often use the sustainable industry classification system provided by SASB [14], [15], [16], we also followed the industry classification standard classified by SASB.

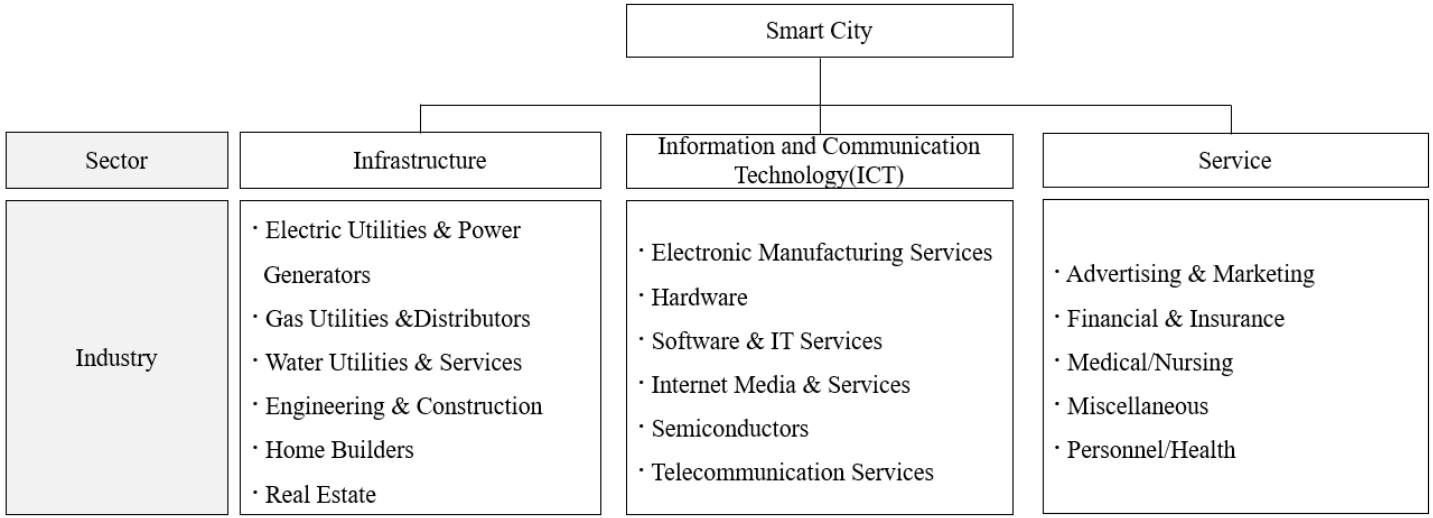

Figure 2: Three Sectors of Smart City based on SASB

1.2 Purpose of Research

Despite having the concept of a sustainable city, we cannot determine the ESG level, which is an indicator that quantitatively and effectively expresses sustainability, of the recent smart city primarily being undertaken by the private sector. There are very few studies showing the ESG level of smart cities or other related studies. In order to solve this problem, we first reviewed the previous research that studied the characteristics of smart cities. Through previous research, three industrial sectors (Infrastructure, ICT, and Service) that play a pivotal role in the smart city could be derived. ESG data of companies in these industrial sectors were used for research and analysis, and their performance was evaluated with the level of the smart city. For analysis, we collected data from 1,334 companies. Based on these data, a comprehensive overview of the ESG level of the smart city was provided through correlation analysis and multiple linear regression analysis, and then, a model formula that can obtain the values of ENV, SOC and GOV was derived. The ESG score can be inferred from the average of each of these. This study is meaningful in that it sought to estimate the level of ESG in smart cities when such attempts or studies associated with such are exceedingly rare when examining existing prior studies. Moreover, it can serve as a reference material when companies seeking to plan a smart city or participate in a smart city demand or determine the ESG target level.

1.3 Research Structure

This study consists of a total of six chapters. Chapter 2 explores the previous studies related to the smart city and ESG. When examining the previous studies related to the smart city, it was confirmed that sustainability is continually mentioned as a characteristic of a smart city, and three industrial sectors that play a crucial role in the smart city could be derived.

Previous studies on the ESG matrix have mainly analyzed the level of ESG disclosure or the correlation between ESG and corporate size or financial variables. We could not find studies or guidelines that comprehensively associated a smart city with ESG or attempted to measure and estimate the ESG level of a smart city. Chapter 3 details the data collection method, type, and data source used to derive the basic model formula. Chapter 4 describes the Pearson correlation analysis method and multiple linear regression analysis method, which are statistical methodologies used in this study. Chapter 5 provides a comprehensive overview of the ESG level of smart cities using the methodologies mentioned in Chapter 4, and a basic model formula that can infer the ESG level of a smart city is derived. Finally, in Chapter 6, conclusions are drawn, and the limitations of this study are included. The overall research approach of this study is shown as Figure 3.

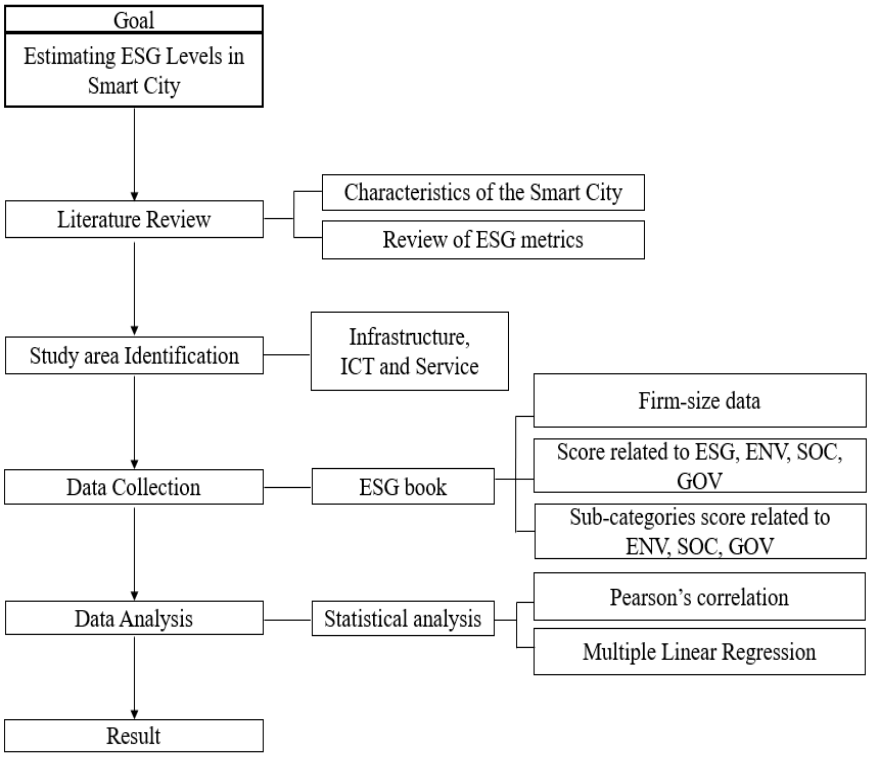

Figure 3: Depicts the overall research approach for this study

Chapter 2

Related Works

This chapter introduces three categories of preceding studies. First, the Characteristics of smart cities and ESG study trends were examined. It was found that smart cities contained the concept of sustainable cities, and ESG study trends were mainly founded on financial correlations. Next, the role of the private sector in smart cities and the importance of ESG were comprehensively reviewed.

2.1 Characteristics of the Smart City

Smart city is not a new concept. It was first created in the 1800s to describe a new city in the western United States and has been changing continuously [17]. In the past, smart cities were also called digital cities [18], ubiquitous cities [19], intelligent cities [20], and creative cities [21]. The definition of a smart city is still evolving without a clear nomenclature [3]. In previous studies on smart cities (see Table 1) the importance of technology, information and communications, flexibility, and sustainability was discussed and emphasized. Table 1 summarize previous studies explaining the characteristics of smart cities. In recent years, sustainability has been

emphasized in smart cities so that future generations can enjoy a better living environment [22]. In the previous studies reviewed, "sustainability" was commonly mentioned, indicating that a smart city contains the concept of a sustainable city. Overall, a smart city is understood as a sustainable city that combines ICT with physical infrastructure to enhance the life quality of the population and provide novel services that can solve and improve urban problems.

Table 1: Characteristics of Smart City

Author	Ref. No.	Definition
Mohammad Shahidepour *et al.* (2018)	[2]	A city center intensified with a variety of innovative solutions to improve infrastructure performance and develop sustainability
Andreia de Bem Machado *et al.* (2021)	[3]	A city solving sustainability issues(Economy,environment and social development) and improving the quality of living on the premises of networking with humane, social capital and ICT
Kancho H. Law *et al.* (2019)	[4]	A city utilizing the information and communications technologies for the sustainable development and enhancement of the quality of the residents' lives as well
G. Piro *et al.* (2012)	[23]	A city providing advanced and innovative ICT services for the citizens to improve the general quality of living
Victoria Fernandez-Anez (2015)	[24]	A smart city is an institution to improve the humane and social capital wisely by means of partnership, sustainable development, and high quality of living based on the stakeholders and local governments

Author	Ref. No.	Definition
Tan Yigitcanlar and Kamruzzaman (2018)	[25]	An ideal format to build up sustainable cities in the 21st century when the balanced and sustainable viewpoint is realized economically, socially, environmentally and institutionally
Chiara Garau and Valentina Maria Pavan (2018)	[26]	A city of technology innovation, new industry a more powerful economy, sustainable environment and enhanced quality of life for the citizens
Alexandar Lara *et al.* (2016)	[27]	A community flexible enough to become a better place for all constituent members and enhance the welfare institutionally, work and enjoy with sustainability
Leonidas G. Anthopoulos (2015)	[28]	The conceptual framework for accessing smart cities consists of resource monitoring,transportation, infrastructure, ICT, utilization and public e-services.The results of smart cities are related to three industrial sectors: construction, ICT, and electronics.

2.2 Review of ESG metrics

The ESG score provides comprehensive and structured data that can be compared for a company. Through this, it plays an integral role in helping stakeholders understand and manage the multifaceted characteristics of a company, such as business ethics and sustainability [29]. Erling Holden *et al.* [30] argued that if a company does not take into account all economic, social, and environmental aspects, it would end up with ”unsustainable” management and would be at risk.

ESG scores assume an important role in promoting ESG transparency by enabling stakeholders and investors to better comprehend and manage the multifaceted nature of ESG, including carbon emissions, climate change, business ethics, and sustainability. In fact, ESG factors, which are indicators of sustainable management, are increasingly being used in corporate decision-making [29]. A growing number of companies are engaged in a wide range of ESG disclosures [10], and this significant issue has been the subject of much attention [12], [31], [32], [33], [34].

Previous studies on ESG analyzed the statistical relationship between the ESG score and financial performance or focused on the correlation between the company size and ESG score(see Table 2).

Both positive and negative evidence were discovered for the relationship between the ESG score and financial performance [35], and it was found that most of the relationship between the ESG score and company size had

a positive correlation. Furthermore, the industry analysis study showed the difference in the ESG score between industries. It provided that the financial industry simply shows a significantly lower score than the Consumer Staples and Utilities industries in the SOC [10], or that it lists the industries with the highest ESG score in the order of industry [27], or that companies in environmentally sensitive fields provide less environmental information than companies in other fields [35]. This paper is different from prior studies in that there are nearly no studies that relate the concept of a smart city to ESG. Following the review of previous ESG-related studies, ESG indicators could be understood as a tool for disclosing sustainable goals and the will or progress toward achieving those goals.

Table 2: Preliminary Study on ESG Analysis

Author	Ref. No.	Definition
Nnbil Tamimi and Rose Sabastianelli (2017)	[10]	The average ESG score was different depending on the industrial sector when 347 firms out of S&P 500 firms, and such differences were found from SOC and GOV. The ESG score was significantly higher in the large companies than medium sized companies.
Grigoris Giannarakis (2013)	[31]	The scale of the firm and the ESG score showed the most significant relation when 366 firms in USA were analyzed.
Fabrizio Crespi and Milena Migliavacca (2020)	[32]	The trend was confirmed that the ESG score escalated for the bigger firms when 727 financial firms were analyzed in 22 countries. In addition, the firms in larger size and revenue displayed a positive linear trend.
Ilze Zumente *et al.* (2020)	[34]	The scores in SOC and GOV were higher than in ENV when 34 firms listed in Balt exchange were analyzed. The ESG score was relevant with the aggregate value of the listed stock. The large companies showed better scores.

Author	Ref. No.	Definition
Omer M Elaskit and Andrew C. Worthington (2014)	[35]	The literature review analysis showed the positive relation between the firm size and the disclosing range in many studies. However, the revenue showed the positive and negative impact simultaneously.
Rim EI Khour *et al.* (2021)	[36]	When 38 listed banks were analyzed.The score on ENV was the lowest and highest in GOV. In addition, the financial achievement of the bank made influence on SOC.
Jeremy Galbreath (2013)	[37]	Australian firms improved the ESG performance as time elapsed when 249 Australian firms were analyzed. Especially, it was improved more in GOV. In addition, it was more improved in energy and material industry.
Amina Buallay *et al.* (2021)	[38]	A regression analysis was performed between the ESG score and Return on Assets(ROA), Return on Equity(ROE), and Tobin's Q(TQ) of the top worldwide 20 smart cities. They founded that the positive significant relationship between ESG and ROA, ROE, but a negative significant relationship between ESG and TQ.

2.3 Review of Smart City and ESG

As a sustainability evaluation indicator, ESG is a core value that realizes sustainability in corporate management [31], [39]. In other words, since implementation and evaluation of sustainability should be a part of the development of a sustainable smart city, ESG and the smart city framework should be viewed from an integrated perspective. Examples of sustainable management include the environment, ethical labor practices, and shared governance among various stakeholders [10]. Recently, the role of smart city planning and development is shifting from government-led initiatives to private sector and citizen-centric cities [40]. The smart city is called a public-private-people (3P) partnership that unites the concept of community cooperation between businesses, governments, and citizens [41], [42]. In fact, the participation of the private sector is recognized as one of the key success factors for smart city implementation [42].

The Republic of Korea has introduced the smart city plan firstly by the name of U-City. But the application of the smart city was insufficient. The main factor for failure was non-involvement of the private firms and lack of governance policy for U-City. Also U-City failed because it was limited to the models of central government only [43].

In Amsterdam, the Netherlands, smart cities are operated by the private sector rather than the government through an open platform called ASC (Amsterdam Smart City) by the method of participation from companies

(40.1%), governments (14.2%), research institutes (13.9%), etc [44]. In the case of Barcelona, Spain, it supports public-private partnerships to implement innovative projects that benefit both businesses and the city [45]. The project aims to promote private sector participation in the development of innovative solutions for current urban problems [46].

In the case of the Eco-City project in France, the goal is to improve the quality of life of citizens by leading the technology and services of private companies such as IBM and Cisco [47]. As such, the role of the private sector is paramount in the development and operation of smart cities. Jonas Breus *et al.* also claimed that the public sector, private businesses and citizens are the key to making cities smarter [48]. As said, the importance of private firms in the smart city was confirmed through the precedent studies. Due to the recent interest in ESG, the number of ESG evaluation agencies has increased [49] and it was possible to extract not only the ESG score of private companies, but also the scores of ENV, SOC and GOV that constitute it. Details of each pillar are below [10], [31], [37], [50].

• Environment (ENV): This includes the management policies concerning environment issues. Namely, the environmental sensation related to electric power and water consumption, carbon emission, waste reduction, environment purification and renewable energy of the firms and the data on greenhouse gas and energy use.

• Social (SOC): Management policies of the firms for the employees, consumers and the community where they are situated, employees' welfare and health, labor-management relation, employee transfer, accidents involving employees, employment diversity, consumer protection, product safety and exchange with the local community.

• Governance (GOV): Management policies to enhance the soundness of the entrepreneurial governance, gender diversity, and independence of board of directors, ethical firm operation, shareholders' rights, transparent tax payment and accounting book management, processes and system to satisfy the communication and requirements from the internal or external stakeholders and etc.

This study provides a comprehensive overview of the current ESG levels of smart cities through corporate data from three industry sectors that influence and contribute to smart cities, and it can be referred to as a guideline when trying to infer the ESG scores. Since there are currently few studies that explore the ESG level from the smart city perspective, the study is meaningful in that it attempted to create the ESG level of the smart city and the basic model formula that can infer it.

In addition, since companies tend to strengthen competitiveness by benchmarking ESG policies or scores of companies that are influential or recognized as peers [33], companies that want to participate in smart cities

can be motivated to pursue sustainability management by referring to the current ESG level of smart cities. The study also helps them to use it as a benchmarking tool for ESG management.

Chapter 3

Methodology

3.1 Data Collection

This study examines the ESG performance status of companies in the infrastructure, ICT, and service fields, which are the backbone of smart cities, and develops a model that derives the ESG scores of smart cities from ENV, SOC and GOV score data of companies in three sectors.

The research sample consists of recent 1,344 data as of December 2021. All data used were collected through web scraping in the online database of the ESG book. Web scraping is the techniques of using to extract content or data from a website. The ESG book has partnered with the Sustainability Accounting Standards Boards (SASB), Task Force on Climate-related Financial Disclosure (TCFD), and International Finance Corporation (IFC) to collect ESG scores from various companies. SASB is a non-profit organization established to develop measurement standards for reported ESG issues. SASB standards provide useful information on sustainability issues [16].

The TCFC is a climate-related task force and establishes recommendations for disclosing accurate and comparable information on risks and opportunities posed by climate change [51]. IFC is the world's largest fi-

nancial institution supporting the private sector, expanding and revitalizing green finance based on ESG investment [52].

The data used is as follows:

(1) Firm-size data

(2) ESG score(ESG/ENV/SOC/GOV)

(3) Sub-categories score of ESG Measurement (ENV/SOC/GOV)

Firm-size data is classified as micro, small, medium and large in their scale. The Firm-size criteria used data classified in ESG book. Generally, based on market capitalization, Micro companies are divided into $50 million to $300 million, Small companies into $300 million to $2 billion, Mid companies into $2 billion to $10 billion, Large companies into $10 billion to $200 billion. The scores in (2) and (3) use a scale of 100 points. (3) Sub-categories are the disclosure of scores by classifying several related topics corresponding to ENV, SOC and GOV into 7, 10, and 5, respectively, as shown in Table 3.

The target region is not limited to a specific country, and the sample includes America, Asia, Europe, and Pacific Rim. All data were collected in Excel format, except for the one missing even one sub-category value among the ESG evaluation companies listed in the ESG book.

After data collection, descriptive statistics were conducted to identify the overall data. Pearson correlation analysis was performed to determine the relationship between the company size and specific ESG scores. Multi-

Table 3: Sub-categories of ESG Measurement

ENV	SOC	GOV
Emissions	Compensation	Business Ethics
Environmental Management	Diversity	Capital Structure
Waste	Employment Quality	Corporate Governance
Environmental Stewardship	Human Rights	Transparency
Resource Use	Labor Rights	Forensic Accounting
Water	Health and Safety	
Environmental Solution	Training and Development	
	Product Quality and Safety	
	Community Relationship	
	Product Access	

ple linear regression analysis was performed to derive the ESG score inference model. In the regression analysis, ENV, SOC and GOV scores were set as dependent variables, and sub-categories corresponding to each column were set as independent variables.

3.2 Pearson's correlation

In order to understand the overall trend of the analysis data, we analyzed the correlation between the company size and ESG score, and the company size and sub-category score. Pearson's correlation analysis analyzes how linear two variables are, in which direction they are linear to, and how large the linear relationship is [53]. The Pearson correlation coefficient has a value between -1 and +1. As the correlation between the two variables

increases in the positive direction, it is closer to +1, and as the correlation between the two variables increases in the negative direction, it appears closer to -1 [54]. On the other hand, if there is no correlation between the two variables, it is 0. In general, we expected that the larger the company, the higher the ESG score.

However, following the analysis of the correlation between the company size and ESG score, the GOV score was found to have no correlation with the company size, indicating that the larger the company size, the higher the score unconditionally. More specifically, among the sub-categories of GOV, Business Ethics, Corporate Governance, and Forensic Accounting were confirmed to be better for small companies.

3.3 Multiple linear regression

Multiple linear regression is a technique to analyze the relationship between two or more independent variables and one dependent variable [55], and is expressed as follows:

$$Y = \beta_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + \ldots + a_n X_n \tag{3.1}$$

Y Represents the dependent variable and is the reference variable that is thought to be affected. β_0 Stands for Constant. X represents the independent variable, is a variable that is thought to have an impact. n represents the

number of independent variables.

For regression analysis, in general, multicollinearity between independent variables should be suspected if the tolerance value is less than 0.1 or the variance inflation factor (VIF) value is 10 or more [53]. Multicollinearity refers to a problem in which an error in regression coefficient estimation occurs when independent variables have an excessively high correlation with each other [11]. As shown in Figure 4, high correlation between independent variables creates a problem that is irrelevant even if it is the same variable, so it is necessary to have independence between variables.

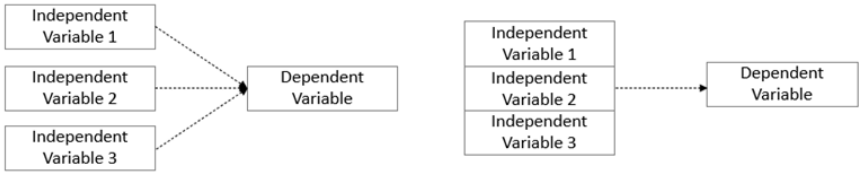

Figure 4: Multicollinearity (left: without multicollinearity, right: when there is multicollinearity)

That is, if three independent variables have an excessively high correlation, it is equivalent to conducting regression analysis of three identical independent variables. In this study, since the tolerance and VIF values all did not exceed the standard, there was no issue of multicollinearity, so there was no problem with interpreting the regression results.

In addition, skewness and kurtosis were checked for normality test of variables used in the analysis. If the absolute value is less than three for skewness and less than seven for kurtosis, it is considered to have normality

[56]. Skewness is a measure indicating the degree of asymmetry. If skewness is positive, the distribution is long-tailed to the right, and if the skewness value is negative, the distribution is long-tailed to the left.

Figure 5: Skewness (left: when the skewness value is positive, right: when the skewness value is negative)

Kurtosis is a measure indicating how sharp a graph is. The larger the kurtosis, the sharper the center. Our analysis data showed that the skewness did not exceed three and the kurtosis did not exceed seven, thus satisfying the normality criterion. Lastly, when checking the residual plot to check the equal variance, equal variance was assumed because the distribution did not take a specific shape.

Chapter 4

Result

After examining the ESG score trend through descriptive statistics and correlation analysis, we sought to create a basic model formula that can infer the ESG score through multiple linear regression analysis.
First, we checked the ESG, ENV, SOC and GOV scores of 1,334 companies through descriptive statistics. ENV was the highest with an average of 56.3 points, and GOV was the lowest with an average of 50.2 points.

GOV provides a framework for transparent and responsible decision-making and excellent management for project success [57]. Khan *et al.* [58] underscored the creation of a governance structure as a strategic means for the transition and operation of smart cities. GOV can be improved by incorporating transparency into ethical behavior and decision-making [59].

In addition, since inter-company partnerships and cooperation for transparency are particularly imperative in large-scale platform projects such as smart cities [60] companies participating in smart cities should focus on GOV. According to Pearson's correlation results, only GOV was found to be unrelated to the company size. Among the sub-categories of GOV, Business Ethics, Corporate Governance, and Forensic Accounting were actu-

ally found to have higher scores in small companies. This may be because small companies focused more on GOV, which is relatively inexpensive to increase their overall ESG score [10].

Through Multiple Linear Regression, a basic model formula that can infer the ESG score was presented. Each score can be calculated through a model formula based on ENV, SOC and GOV scores and their sub-categories, and ESG scores can be inferred from their averages.

4.1 Descriptive statistics and correlations Analysis by size

Table 4 shows the descriptive statistical results for ESG, ENV, SOC and GOV. The sample consists of 42% (n=554) in the infrastructure sector, 34% (n=454) in the ICT sector, and 24% (n=326) in the service sector. ESG scores ranged from the lowest of 29.7 to the highest of 72.9. Among the three columns constituting ESG, ENV was the highest at 56.3 points and GOV was the lowest at 50.2 points. In fact, as 60 companies showed a GOV of less than 30, it appears that several companies are relatively sluggish in the GOV.

Table 4: Descriptive statics of variables

Variable	N	Average	SD	Minimum	Maximum
ESG	1334	53.5	7.3	29.7	72.9
ENV	1334	56.3	12.68	28.6	86.8
SOC	1334	56.1	7.76	30.9	74.2
GOV	1334	50.2	12.21	16.2	80.8

Table 5 analyzes the correlation between the company size and each score. ESG, ENV, and SOC showed a positive correlation in which the score increased as the company size increased, whereas the GOV showed an insignificant negative correlation. Figure 6 shows this relationship as a plot. Only the GOV score showed a trend that was not correlated with the firm size.

Table 5: Correlation between Firm Size and ESG, ENV, SOC, GOV Scores

Variable		Size
ESG	Pearson's r	0.208***
	p-value	⟨0.001
ENV	Pearson's r	0.356***
	p-value	⟨0.001
SOC	Pearson's r	0.309***
	p-value	⟨0.001
GOV	Pearson's r	-0.022
	p-value	0.426

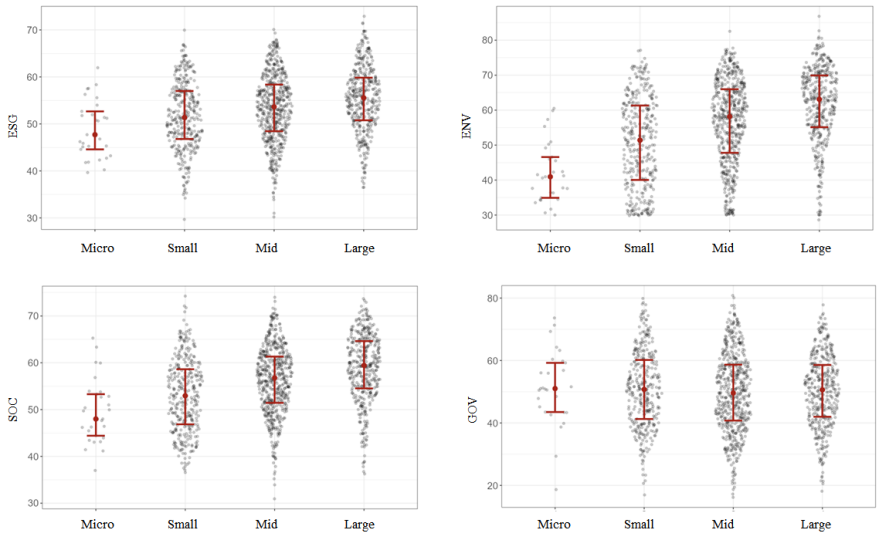

Figure 6: Correlation plot

Next, in order to examine which sector is leading this trend, the three sectors of Infrastructure, ICT, and Services were examined separately. These results are shown in tables and graphs in Table 6 and Figure 7, respectively. When checking the results, as in Table 5, it was confirmed that ENV

and SOC scores tended to be higher as the size increased in all three sectors, but the GOV score had no correlation with the size. Currently, companies of all sizes are not paying attention to GOV, so it is sluggish. Meanwhile, this can be interpreted that there is more room to increase the GOV score. Large projects such as smart cities are stand-alone temporary organizations that work together for a limited time in an uncertain environment [61]. Such a mega project is a very risky venture and is difficult to manage. Much of the literature on the performance of these large projects also relates to decision-making, strategy and governance, stakeholder engagement and management, and so forth [62]. Smart city projects that need to cover various organizations improve transparency between different organizational levels to achieve the project's goals, which also contributes to corporate performance as it positively affects the exchange of relevant information among various stakeholder groups [57]. Although most companies seem to be sluggish in GOV, it seems that GOV plays a significant role for the success of large projects such as a smart city and the sustainable management of the companies that comprise it, so they should pay more attention to it voluntarily.

Table 6: ESG, ENV, SOC, GOV Scores by 3 sectors by size

Size	Infrastructure	ESG ICT	Service	Infrastructure	ENV ICT	Service
Micro	49.25	51.26	46.59	44.85	41.39	38.99
Small	52.6	51.35	50.91	55.76	48.41	45.75
Mid	54.26	53.65	51.27	60.01	56.84	49.19
Large	55.23	56.15	54.14	63.11	62.24	57.39
Size	Infrastructure	SOC ICT	Service	Infrastructure	GOV ICT	Service
Micro	50.72	48.41	49.18	50.83	56.5	47.36
Small	54.48	51.96	51.94	49.50	51.97	51.72
Mid	56.48	57.18	54.55	49.38	50.04	50.19
Large	58.58	59.09	54.14	48.36	51.59	50.58

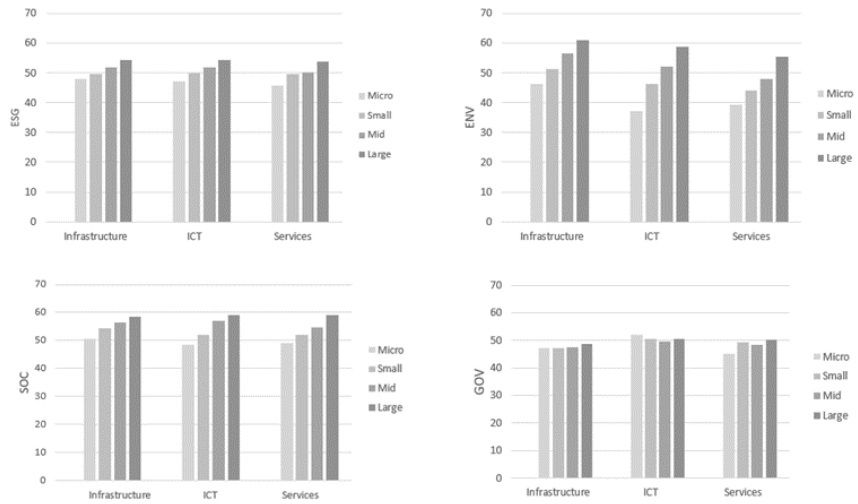

Figure 7: ESG, ENV, SOC, GOV Scores by 3sectors by size

To take a closer look, as shown in Table 7, we examined the ESG level of smart cities through correlation analysis by sub-categories of ENV, SOC and GOV and company size. In Table 7, in ENV, the scores of all sub-categories tend to increase as the company size increases. In particular, the bigger companies are better at Emissions and Resource Use. In SOC, the bigger the company, the better it was at Training and Development and Product Access. It was a surprising result that the correlation of compensation according to the company size was low, which means that some small companies may pay many compensation to attract more talents.

In GOV, both positive and negative correlations were observed at the same time. A significant negative correlation was found for Business Ethics, Corporate Governance, and Forensic Accounting. In these three categories, small companies were found to score rather higher. Business Ethics relates to issues such as corporate corruption, political contributions and antitrust, while Corporate Governance relates to policies or subjects surrounding governance issues such as boards and committees, shareholder rights, and insider trading. Forensic Accounting is related to whether a company's reported earnings are a good representation of the company's financial health.

ENV is seen as a pillar that requires capital commitment such as improvement of processes related to the environment such as greenhouse gas or carbon emission or investment in facilities. In particular, Emissions are related to costs as they include emissions of greenhouse gases and other

air pollutants. Others include renewable energy, clean energy products and management, which involve technology as well as costs. Therefore, it is interpreted that there may be a difference depending on the investment capacity between small and large companies.

In the case of SOC, it seems reasonable that the larger the company, the more training programs for its employees. And it is interpreted that differences are shown based on company size since more public interest or participation lead to receiving more social attention. However, GOV does not show a consistent increase according to the size of the companies.

The reason is first, small companies may have focused on relatively inexpensive GOV to increase their overall ESG score[10]. In this regard, as shown in Figure 7, the trends between the ESG score and ENV, SOC and GOV were examined. As a result, it was confirmed that the GOV had the most influence in order to raise the ESG score by showing the shape closest to a straight line in the GOV. Second, the average GOV score is the lowest, companies of all sizes as a whole do not pay much attention to GOV's. Therefore, it is thought that there may be no relationship between the score and the size.

Table 7: Correlation between Firm Size and Sub-categories

ENV	Size	SOC	Size	GOV	Size
Emissions	0.376***	Compensation	0.064*	Business Governance	-0.097***
Environmental Management	0.257***	Diversity	0.132***	Capital Structure	0.115***
Waste	0.254***	Employment Quality	0.254***	Corporate Governance	-0.104***
Environmental Stewardship	0.256***	Human Rights	0.229***	Transparency	0.271***
Resource Use	0.344***	Labour Rights	0.178***	Forensic Accounting	-0.164***
Water	0.261***	Health and Safety	0.143***		
Environmental Solution	0.184***	Training and Development	0.291***		
		Product Quality and Safety	0.085***		
		Community Relationship	0.278***		
		Product Access	0.318***		

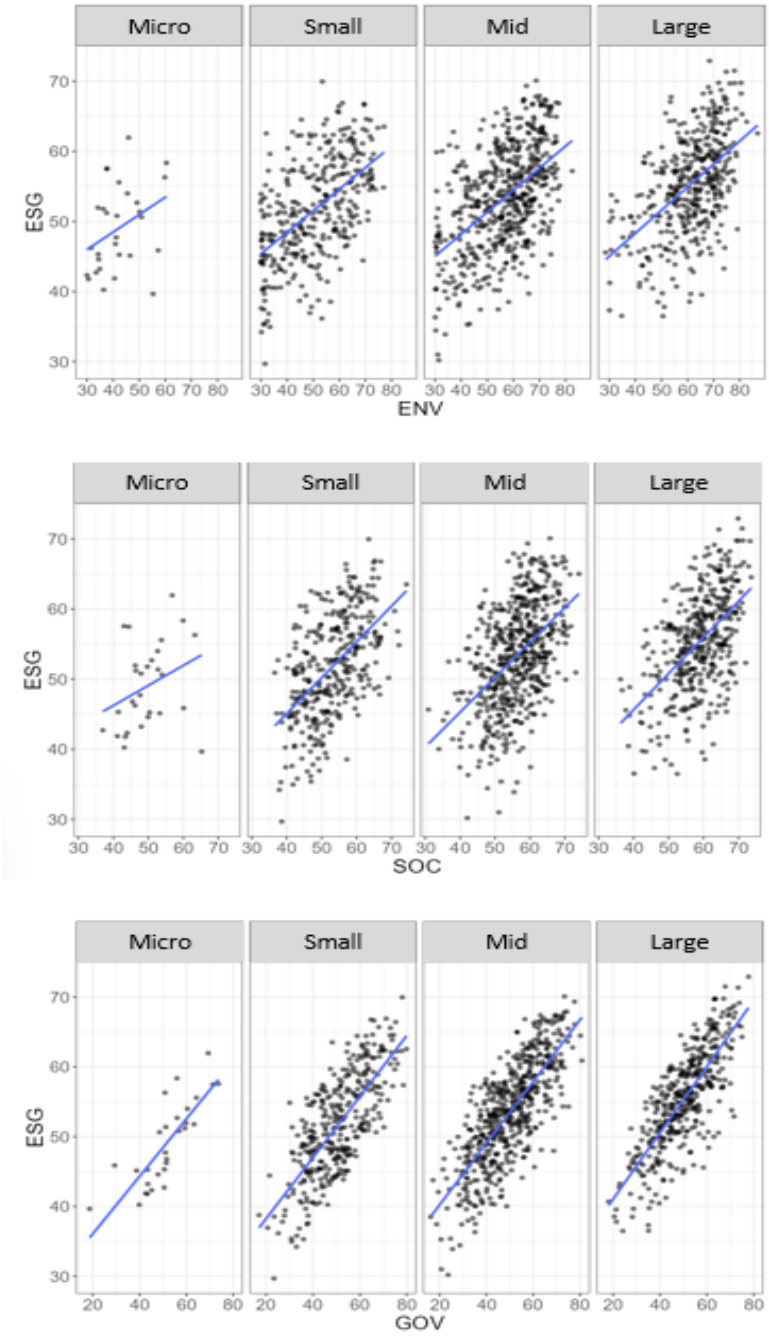

Figure 8: Relationship trends between ESG and ENV, SOC, GOV pillars

4.2 Derive ESG score calculation prediction model

Multiple regression analysis was performed to suggest a basic model formula for estimating the ESG score. There was no problem in multicollinearity because neither the tolerance and VIF values exceeded the standards, nor there was no problem in interpreting the regression results because both the skewness and kurtosis test results did not exceed the standards because they follow normality.

The unstandardized Beta (Ustd β) value represents how much the dependent variable increases when the independent variable increases by 1. That is, if Ustd β is positive (+), it indicates that as the independent variable increases, the dependent variable also increases. If Ustd β is negative (-), it indicates that as the independent variable increases, the dependent variable decreases. Dependent variables were ENV, SOC and GOV, and independent variables were sub-categories corresponding to each column.

Table 8, Table 9, and Table 10 show the results of multiple linear regression for ENV, SOC and GOV, respectively. multiple linear regression plots for this are shown in Figure 8, Figure 9, and Figure 10.

For example, in Table 8, if the ENV score increases by 1 in Emissions, which is a sub-category of ENV, it indicates that the ENV score increases by 0.123 points, and if 1 point increases in Environmental Management, the ENV score increases by 0.162 points. In this regard, it can be seen that the relative effect on ENV score is greater for Environmental Management

than Emissions. It is such Standardized Coefficients β (Std β) value that can identify this relative influence. For example, in raising the ENV score, it is interpreted that Emissions has an influence of 12.6 and Environmental Management has an influence of 17.9.

Table 8: Multiple linear regression between ENV score and Sub-categories

ENV	Ustd β	Std β	Sig.	Tolerance	VIF	Skewness	Kurtosis
(Constant)	-0.295						
Emissions	0.123	0.126	⟨0.001	0.341	2.93	-0.283	-0.727
Environmental Management	0.162	0.179	⟨0.001	0.403	2.479	-0.115	-1.226
Waste	0.168	0.215	0.000	0.529	1.902	-0.410	-0.793
Environmental Stewardship	0.103	0.162	⟨0.001	0.473	2.14	0.193	-1.150
Resource Use	0.188	0.232	0.000	0.408	2.450	-0.456	-0.699
Water	0.124	0.158	⟨0.001	0.596	1.677	0.249	-1.270
Environmental Solution	0.141	0.225	0.000	0.736	1.359	0.053	-1.371
N	1,334						
Adjust R^2	0.970						

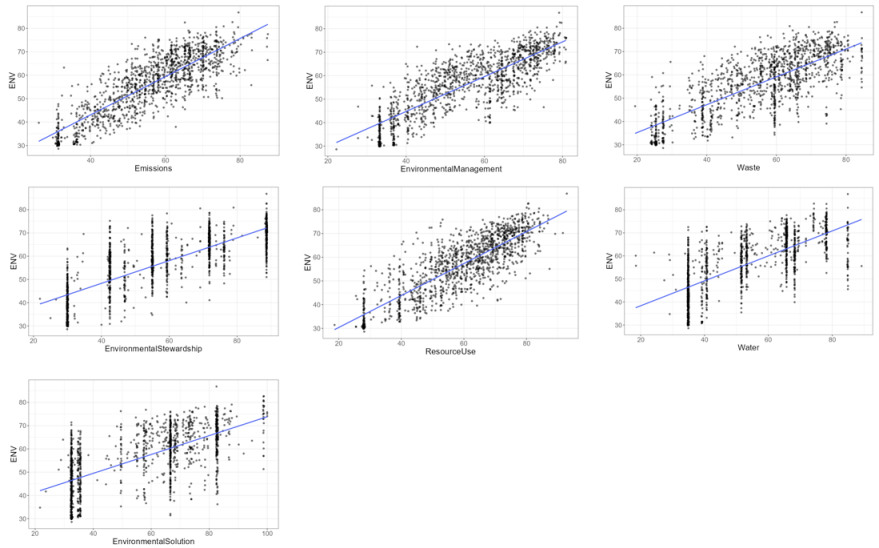

Figure 9: Regression plot between ENV and Sub-categories

Table 9: Multiple linear regression between SOC score and Sub-categories

SOC	Ustd β	Std β	Sig.	Tolerance	VIF	Skewness	Kurtosis
(Constant)	0.735						
Compensation	0.066	0.101	⟨0.001	0.877	1.140	-0.998	0.383
Diversity	0.129	0.143	⟨0.001	0.754	1.327	-0.148	-0.007
Employment Quality	0.122	0.240	⟨0.001	0.700	1.428	0.090	-1.499
Human Rights	0.080	0.161	⟨0.001	0.541	1.849	-0.193	-1.013
Labour Rights	0.067	0.120	⟨0.001	0.475	2.104	-0.361	-0.679
Health and Safety	0.121	0.173	⟨0.001	0.574	1.742	-0.350	-0.687
Training and Development	0.066	0.132	⟨0.001	0.642	1.557	-1.701	2.191
Product Quality and Safety	0.175	0.238	⟨0.001	0.683	1.463	0.301	-0.342
Community Relationship	0.085	0.146	⟨0.001	0.536	1.866	-0.093	-0.366
Product Access	0.082	0.140	⟨0.001	0.733	1.365	0.485	-0.720
N	1,334						
Adjust R^2	0.964						

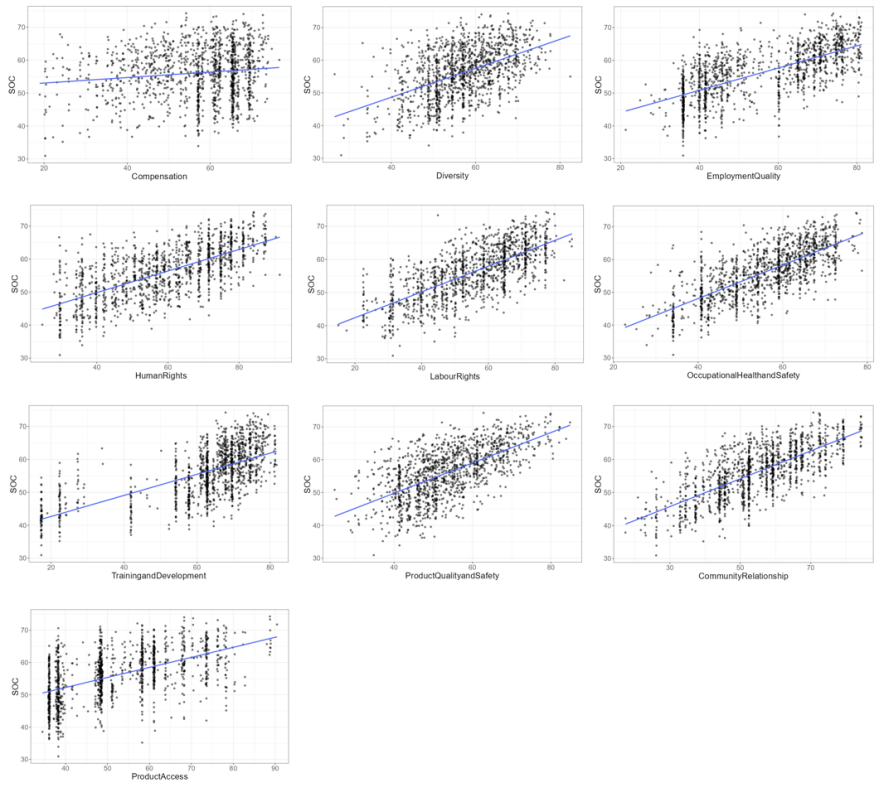

Figure 10: Regression plot between SOC and Sub-categories

Table 10: Multiple linear regression between GOV score and Sub-categories

GOV	Ustd β	Std β	Sig.	Tolerance	VIF	Skewness	Kurtosis
(Constant)	0.068						
Business Ethics	0.156	0.126	0.000	0.919	1.088	-1.579	3.949
Capital Structure	0.312	0.179	0.000	0.980	1.021	-0.027	-1.119
Corporate Governance	0.143	0.215	⟨0.001	0.911	1.097	-0.594	-0.331
Transparency	0.069	0.162	⟨0.001	0.972	1.029	-0.386	-0.720
Forensic Accounting	0.320	0.232	0.000	0.994	1.006	-0.384	-0.477
N	1,334						
Adjust R^2	0.980						

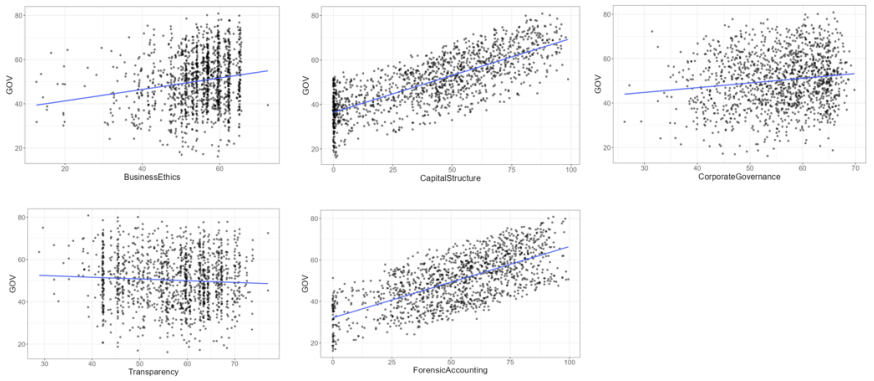

Figure 11: Regression plot between GOV and Sub-categories

As a result of multiple linear regression analysis in Table 8, Table 9, and Table 10, it was confirmed that they were statistically significant in all sub-categories. The regression equation derived from this is as follows: Assuming that the value of each sub-category is known, each ENV, SOC and GOV score can be calculated through our regression model, and the ESG score of a smart city can be inferred from their average.

- $\mathrm{ENV(Y)} = -0.295 + 0.123\mathrm{X}_{1(Emissions)} + 0.162X_{2(Environmental\ Management)} + 0.168X_{3(Waste)} + 0.103X_{4(Environmental\ Stewardship)} + 0.188X_{5(Resource\ Use)} + 0.124X_{6(Water)} + 0.141X_{7(Environmental\ Solution)}$
- $\mathrm{SOC(Y)} = 0.735 + 0.066\mathrm{X}_{1(Compensation)} + 0.129X_{2(Diversity} + 0.122X_{3(Employment\ Quality)} + 0.080X_{4(Human\ Rights)} + 0.067X_{5(Labour\ Rights)} + 0.121X_{6(Health\ and\ Safety)} + 0.066X_{7(Training\ and\ Development)} + 0.175X_{8(Product\ Quality\ and\ Safety)} + 0.085X_{9(Community\ Relationship)} + 0.082X_{10(Product\ Access)}$
- $\mathrm{GOV(Y)} = 0.068 + 0.156\mathrm{X}_{1(Business\ Ethics)} + 0.312X_{2(Capital\ Structure)} + 0.143X_{3(Corporate\ Governance)} + 0.069X_{4(Transparency)} + 0.320X_{5(Forensic\ Accounting)}$

According to the proposed model, it was found that the Resource Use category took the highest proportion to increase the ENV score, the Product Quality and Safety category to increase the SOC score, and the Forensic Accounting category to increase the GOV score.

In a smart city, various technologies that can use resources such as en-

ergy and water as efficiently as possible must be combined with information and communication technology (ICT) to provide a service that induces optimized resource consumption. In essence, being sustainable is a form of enabling older generations to consume less and pollute less so that future generations can enjoy a better living environment [14].

Since optimized resource consumption is ultimately about consuming less resources, it seems reasonable that the related Resource Use and Waste category should have the highest weight in the ENV score.

In SOC, it was found that Product Quality and Safety, and Diversity accounted for a high proportion. According to the ESG book, Product Quality and Safety consists of policies or monitoring related to product or service quality, safety, and customer satisfaction, etc. Diversity encompasses equal opportunities for women and minorities in workers and boards, and diversity of suppliers. Based on previous research [63] that participation of the women's board was effective, it could be better to improve female board election, employee and supplier's diversity, and female members' participation in boards. It was found that Forensic Accounting and Capital Structure occupy a high proportion in GOV. Forensic Accounting is the degree to which a company's reported earnings adequately represent its actual financial position. Capital Structure is an sub-category that evaluates the relative leverage level and debt ratio, and whether these are reflected in decision-making.

ESG scores are used to identify companies that can perform better in the long run, taking into account the principle of financial importance. There is no right and sure way to build a smart city, but investment in smart cities must continue to provide a better quality of life and a cleaner environment. In Table 11, the result of further analysis, it was confirmed that only GOV had a significant positive correlation with Return on Assets (ROA). In the case of large projects such as smart cities, sound financial management as well as management decision-making and communication with stakeholders seems to be important because “win-win growth” is made as a platform of a critical smart community.

Table 11: Correlation between ROA and ENV, SOC, GOV

Variable		ROA
ENV	Pearson’s r	0.064
	p-value	0.146
	N	510
SOC	Pearson’s r	0.037
	p-value	0.400
	N	510
GOV	Pearson’s r	0.227***
	p-value	⟨0.001
	N	510

4.3 Verification of ESG Score Prediction Model

Since there is no previously disclosed ESG level of a smart city, there is no subject that can compare and verify the model formula derived from this study. Hence, we collected the current (as of June 2022) score data of 500 companies out of 1,334 company data as of December 2021 used to derive the model formula, and compared the score and the score tested using the model formula. The difference between the actual and tested values of ENV, SOC and GOV was confirmed to be less than 1% of the actual value. This can be interpreted to mean that the performance of the derived model formula is high, and it is not a big issue in inferring the ESG score.

Table 12: Difference between actual value and calculated value

Category (Average of 500 companies)	ENV	SOC	GOV
Actual Value	51.48	54.01	50.46
Calculated Value	51.59	54.08	50.51
Difference(Actual Value - Calculated Value)	-0.11	-0.07	-0.05

Chapter 5

Discussions

5.1 Discussion and Summary

In this study, we sought to examine the levels of E, S, and G of the current smart city through the data of companies belonging to the Infrastructure, ICT, and Service sectors that play a major role in the current smart city. We tried to derive a model formula that can infer the ESG score through multiple linear regression analysis as a next step. According to the descriptive statistical results of 1,334 company data (as of December 2021) collected through web scraping for our analysis, the current GOV score was the lowest. In previous studies, institutional investors said that governance factors have a great influence on investment decisions [60], so GOV evaluation cannot be left out in the smart city planning stage. In addition, smart city projects, which need to cover various organizations, improve transparency between different organizational levels to achieve the project's goals. This positively affects the exchange of relevant information among various stakeholder groups, thus contributing to the performance of the enterprise [59].

Currently, GOV seems to have the lowest average score as companies of all sizes do not pay much attention to it. However, it also means that

companies have room to further raise the GOV score, and it seems important for companies to pay more attention to the GOV for shared growth for the creation of smart cities. This is because large projects such as smart cities are made up of platforms with various stakeholders.

In the results of correlation analysis between ENV, SOC and GOV scores and company size, the scores of ENV and SOC showed a consistent trend with increasing company size, but GOV had no relation with company size. To see more detailed results, the correlation between sub-categories of each column and the company size was conducted. In this result, the sub-category scores of ENV and SOC showed a positive correlation as the company size increased, but both positive and negative correlations were found in the GOV. This is thought to be inconsistent with the size because companies as a whole are sluggish in GOV. This paper emphasizes once again that companies should voluntarily pay more attention to GOV.

The basic model formula derived through multiple linear regression analysis could determine which sub-categories had a high proportion in each column (ENV, SOC, GOV). When the derived model formula was verified through 500 company data as of June 2022, the error was less than 1%, confirming the high performance of the predictive model. Although there are very few studies that assess the ESG level of smart cities or relate them, it is meaningful in that this study attempted to estimate the level. In addition, the influence between each column constituting ESG and its sub-categories

was confirmed. This can be a reference material for companies planning a smart city or participating in a smart city wants to requests or determines the ESG target level.

5.2 Limitation and Future study

However, this study has several limitations as follows: First, this study was based only on the data as of December 2021, and it was not possible to examine whether the data improved or declined over time. Year-by-year analysis is recommended because even if the score is low, if the score is steadily increasing, there is room for improvement in the future. Second, the limitations of the predictive model can be seen in that there is no target to compare and verify the model formula derived through this study because there is no previously disclosed ESG level of the smart city. Third, This study investigated several countries to examine, but more in-depth results can be expected when the countries are divisively analyzed. If each country is analyzed separately, the weight of the variable may appear differently for each country. Fourth, this study is meaningful in that it tried to examine the ESG performance level of smart cities. However, the data from 1,334 companies cannot completely reflect the ESG level of smart cities. When smart cities are activated in the future, research is needed to collect and analyze the ESG scores of companies that are actually participating.

Bibliography

[1] "Our world in data." https://ourworldindata.org/grapher/urban-and-rural-population-2050. Accessed: 2022-10-31.

[2] M. Shahidehpour, Z. Li, and M. Ganji, "Smart cities for a sustainable urbanization: Illuminating the need for establishing smart urban infrastructures," *IEEE Electrification Magazine*, vol. 6, no. 2, pp. 16–33, 2018.

[3] A. d. B. Machado, J. Rodrigues dos Santos, M. F. Richter, and M. J. Sousa, "Smart cities: Building sustainable cities," in *Green Technological Innovation for Sustainable Smart Societies*, pp. 1–19, Springer, 2021.

[4] K. H. Law and J. P. Lynch, "Smart city: Technologies and challenges," *IT Professional*, vol. 21, no. 6, pp. 46–51, 2019.

[5] R. P. Dameri and A. Cocchia, "Smart city and digital city: twenty years of terminology evolution," in *X Conference of the Italian Chapter of AIS, ITAIS*, vol. 1, 2013.

[6] H. Ahvenniemi, A. Huovila, I. Pinto-Seppä, and M. Airaksinen, "What are the differences between sustainable and smart cities?," *Cities*, vol. 60, pp. 234–245, 2017.

[7] Y. H. Kwak and J. Lee, "Toward sustainable smart city: Lessons from 20 years of korean programs," *IEEE Transactions on Engineering Management*, 2021.

[8] A. Al-Jalahma, H. Al-Fadhel, M. Al-Muhanadi, and N. Al-Zaimoor, "Environmental, social, and governance (esg) disclosure and firm performance: Evidence from gcc banking sector," in *2020 International*

Conference on Decision Aid Sciences and Application (DASA), pp. 54–58, IEEE, 2020.

[9] A. Lai, G. Melloni, and R. Stacchezzini, "Corporate sustainable development: is 'integrated reporting'a legitimation strategy?," *Business Strategy and the Environment*, vol. 25, no. 3, pp. 165–177, 2016.

[10] N. Tamimi and R. Sebastianelli, "Transparency among s&p 500 companies: An analysis of esg disclosure scores," *Management Decision*, vol. 55, no. 8, pp. 1660–1680, 2017.

[11] A. Aouadi and S. Marsat, "Do esg controversies matter for firm value," *Evidence form International*, 2018.

[12] A. Awaysheh, R. A. Heron, T. Perry, and J. I. Wilson, "On the relation between corporate social responsibility and financial performance," *Strategic Management Journal*, vol. 41, no. 6, pp. 965–987, 2020.

[13] "Sustainable industry classification system, sasb(sustainability accounting standards board)." https://www.sasb.org/find-your-industry/. Accessed: 2022-05-11.

[14] N. C. Lynch, M. F. Lynch, and D. B. Casten, "The expanding use of sustainability reporting," *The CPA Journal*, vol. 84, no. 3, p. 18, 2014.

[15] A. S. Manikas, J. R. Kroes, and B. P. Foster, "Does the importance of environmental issues within an industry affect the relationship between lean operations and corporate financial performance?," *Sustainable Production and Consumption*, vol. 27, pp. 2112–2120, 2021.

[16] C. Consolandi, R. G. Eccles, and G. Gabbi, "How material is a material issue? stock returns and the financial relevance and financial intensity of esg materiality," *Journal of Sustainable Finance & Investment*, pp. 1–24, 2020.

[17] R. Susanti, S. Soetomo, I. Buchori, and P. Brotosunaryo, "Smart growth, smart city and density: In search of the appropriate indicator

for residential density in indonesia," *Procedia-Social and Behavioral Sciences*, vol. 227, pp. 194–201, 2016.

[18] A. Aurigi, *Making the digital city: the early shaping of urban Internet space*. Routledge, 2016.

[19] S.-H. Lee, T. Yigitcanlar, J.-H. Han, and Y.-T. Leem, "Ubiquitous urban infrastructure: Infrastructure planning and development in korea," *Innovation*, vol. 10, no. 2-3, pp. 282–292, 2008.

[20] N. Komninos, *Intelligent cities and globalisation of innovation networks*. Routledge, 2008.

[21] S. B. Letaifa, "How to strategize smart cities: Revealing the smart model," *Journal of business research*, vol. 68, no. 7, pp. 1414–1419, 2015.

[22] M. Castells, "Urban sustainability in the information age," *City*, vol. 4, no. 1, pp. 118–122, 2000.

[23] G. Piro, I. Cianci, L. A. Grieco, G. Boggia, and P. Camarda, "Information centric services in smart cities," *Journal of Systems and Software*, vol. 88, pp. 169–188, 2014.

[24] V. Fernandez-Anez, "Stakeholders approach to smart cities: A survey on smart city definitions," in *International conference on smart cities*, pp. 157–167, Springer, 2016.

[25] T. Yigitcanlar and M. Kamruzzaman, "Does smart city policy lead to sustainability of cities?," *Land use policy*, vol. 73, pp. 49–58, 2018.

[26] C. Garau and V. M. Pavan, "Evaluating urban quality: Indicators and assessment tools for smart sustainable cities," *Sustainability*, vol. 10, no. 3, p. 575, 2018.

[27] A. P. Lara, E. M. Da Costa, T. Z. Furlani, and T. Yigitcanla, "Smartness that matters: towards a comprehensive and human-centred char-

acterisation of smart cities," *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 2, no. 2, p. 8, 2016.

[28] L. G. Anthopoulos, "Understanding the smart city domain: A literature review," *Transforming city governments for successful smart cities*, pp. 9–21, 2015.

[29] M. Cappucci, "The esg integration paradox," *Journal of Applied Corporate Finance*, vol. 30, no. 2, pp. 22–28, 2018.

[30] E. Holden, K. Linnerud, D. Banister, V. J. Schwanitz, and A. Wierling, *The imperatives of sustainable development: needs, justice, limits*. Routledge, 2017.

[31] G. Giannarakis, "The determinants influencing the extent of csr disclosure," *International Journal of Law and Management*, 2014.

[32] F. Crespi and M. Migliavacca, "The determinants of esg rating in the financial industry: the same old story or a different tale?," *Sustainability*, vol. 12, no. 16, p. 6398, 2020.

[33] E. Clementino and R. Perkins, "How do companies respond to environmental, social and governance (esg) ratings? evidence from italy," *Journal of Business Ethics*, vol. 171, no. 2, pp. 379–397, 2021.

[34] I. Zumente, N. Lace, and J. Bistrova, "Esg disclosure patterns in the baltics," *Business and management*, pp. 28–37, 2020.

[35] O. M. Elsakit and A. C. Worthington, "The impact of corporate characteristics and corporate governance on corporate social and environmental disclosure: A literature review," *International Journal of Business and Management*, vol. 9, no. 9, p. 1, 2014.

[36] R. El Khoury, N. Nasrallah, and B. Alareeni, "The determinants of esg in the banking sector of mena region: a trend or necessity?," *Competitiveness Review: An International Business Journal*, 2021.

[37] J. Galbreath, "Esg in focus: The australian evidence," *Journal of business ethics*, vol. 118, no. 3, pp. 529–541, 2013.

[38] A. Buallay, R. El Khoury, and A. Hamdan, "Sustainability reporting in smart cities: A multidimensional performance measures," *Cities*, vol. 119, p. 103397, 2021.

[39] S. Kengkathran, "Environmental, social and governance (esg) disclosure and its impact on financial performance of top 100 companies in malaysia and australia," 2019.

[40] Z. D. W. Putra and W. G. van der Knaap, "Urban innovation system and the role of an open web-based platform: The case of amsterdam smart city," *Journal of Regional and City planning*, vol. 29, no. 3, pp. 234–249, 2018.

[41] A. Hayar and G. Betis, "Frugal social sustainable collaborative smart city casablanca paving the way towards building new concept for" future smart cities by and for all"," in *2017 Sensors Networks Smart and Emerging Technologies (SENSET)*, pp. 1–4, IEEE, 2017.

[42] R. P. Dameri, E. Negre, and C. Rosenthal-Sabroux, "Triple helix in smart cities: a literature review about the vision of public bodies, universities, and private companies," in *2016 49th Hawaii international conference on system sciences (HICSS)*, pp. 2974–2982, IEEE, 2016.

[43] H. Jang and K. Kim, "A study on improving korean authentication systems for smart cities," 2020.

[44] Y. J. Park, "Strategy for building smart city as a platform of the 4 th industrial revolution," *Journal of Digital Convergence*, vol. 17, no. 1, pp. 169–177, 2019.

[45] I. Capdevila and M. I. Zarlenga, "Smart city or smart citizens? the barcelona case," *Journal of Strategy and Management*, 2015.

[46] T. Bakıcı, E. Almirall, and J. Wareham, "A smart city initiative: the case of barcelona," *Journal of the knowledge economy*, vol. 4, no. 2, pp. 135–148, 2013.

[47] E. Jolivet and A. Bond, "Smart-eco cities in france: Trends and city profiles 2017," *University of Toulouse I, Capitole, Toulouse*, 2018.

[48] J. Breuer, N. Walravens, and P. Ballon, "Beyond defining the smart city. meeting top-down and bottom-up approaches in the middle," *TeMA-Journal of Land Use, Mobility and Environment*, 2014.

[49] M. J. LaBella, L. Sullivan, J. Russell, and D. Novikov, "The devil is in the details: the divergence in esg data and implications for responsible investing," *New York: QS Investors*, 2019.

[50] B. R. Auer and F. Schuhmacher, "Do socially (ir) responsible investments pay? new evidence from international esg data," *The Quarterly Review of Economics and Finance*, vol. 59, pp. 51–62, 2016.

[51] L. Gao and L. Liu, "Corporate sustainability reporting framework and implications for university governance transformation," in *2021 The 7th International Conference on Frontiers of Educational Technologies*, pp. 157–161, 2021.

[52] G. Inderst and F. Stewart, "Incorporating environmental, social and governance (esg) factors into fixed income investment," *World Bank Group publication, April*, 2018.

[53] N. Senaviratna, T. Cooray, *et al.*, "Diagnosing multicollinearity of logistic regression model," *Asian Journal of Probability and Statistics*, vol. 5, no. 2, pp. 1–9, 2019.

[54] P. Schober, C. Boer, and L. A. Schwarte, "Correlation coefficients: appropriate use and interpretation," *Anesthesia & Analgesia*, vol. 126, no. 5, pp. 1763–1768, 2018.

[55] B. K. Slinker and S. A. Glantz, "Multiple linear regression: accounting for multiple simultaneous determinants of a continuous dependent variable," *Circulation*, vol. 117, no. 13, pp. 1732–1737, 2008.

[56] E. Ryu, "Effects of skewness and kurtosis on normal-theory based maximum likelihood test statistic in multilevel structural equation modeling," *Behavior research methods*, vol. 43, no. 4, pp. 1066–1074, 2011.

[57] R. Müller, *Project governance*. Routledge, 2017.

[58] H. H. Khan, M. N. Malik, R. Zafar, F. A. Goni, A. G. Chofreh, J. J. Klemeš, and Y. Alotaibi, "Challenges for sustainable smart city development: A conceptual framework," *Sustainable Development*, vol. 28, no. 5, pp. 1507–1518, 2020.

[59] J. K. Pinto, "Project management, governance, and the normalization of deviance," *International journal of project management*, vol. 32, no. 3, pp. 376–387, 2014.

[60] S. R. Park and J. Y. Jang, "The impact of esg management on investment decision: Institutional investors' perceptions of country-specific esg criteria," *International Journal of Financial Studies*, vol. 9, no. 3, p. 48, 2021.

[61] E. W. Merrow, *Industrial megaprojects: concepts, strategies, and practices for success*. John Wiley & Sons, 2011.

[62] J. Denicol, A. Davies, and I. Krystallis, "What are the causes and cures of poor megaproject performance? a systematic literature review and research agenda," *Project Management Journal*, vol. 51, no. 3, pp. 328–345, 2020.

[63] P. Fahad and P. M. Rahman, "Impact of corporate governance on csr disclosure," *International Journal of Disclosure and Governance*, vol. 17, no. 2, pp. 155–167, 2020.

Abstract

도시화로 인해 인구 밀도가 높아지면서 도시에 거주하는 사람들에게 최적의 여건을 조성하는 것을 목표로 하는 종합적인 지속가능성 전략이 필요하다. 스마트시티는 시민들에게 다양한 서비스를 제공하는 정보통신기술(ICT)과 물리적 인프라를 통합하여 도시화의 과제를 해결하기 위해 등장했다. 전 세계적으로 더 많은 스마트시티가 건설됨에 따라 스마트시티를 재정 지원, 개발 및 유지하는 데 도움이 될 수 있는 스마트시티의 환경, 사회 및 거버넌스 (ESG) 성과를 이해하는 것이 중요하다. 최근의 스마트시티는 공공기관이나 정부 보다는 민간기업의 주도로 개발된다고 할 때, 스마트시티에 참여하는 기업들의 ESG 항목이 스마트시티의 지속적인 운영에 필수적인 영향을 미칠 것이기 때문이다. ESG는 기업의 지속가능성을 증명하는 정량적, 효과적 도구이다. 그러나 스마트시티의 ESG 수준을 살펴보거나, 이를 이해하기 위한 특정 절차, 지표 또는 가이드라인에 대한 연구는 거의 드물다. 이를 해결하기 위해 본 연구에서는 스마트시티에서 중요한 역할을 하는 Infastructure, ICT 및 Service 부문의 ESG 점수데이터를 활용하여 현재 스마트시티의 ESG 수준에 대한 포괄적 개요를 살펴보았다. 그런 다음 3개 부문의 ESG 점수를 사용해서 다중 선형 회귀분석을 실시하여 스마트시티의 ESG 수준을 유추해볼 수 있는 기본적인 모델을 제시하였다. 본 연구는 기존에는 없었던 스마트시티의 ESG 수준을 추론해볼 수 있는 기본적인 모델을 개발하고자 시도했다는데에 의

미를 가진다. 또한 선행연구에 따르면, 기업은 영향력 있거나 동종업체로 인식되는 기업의 ESG 정책이나 점수를 벤치마킹하여 경쟁력을 강화하려 하기 때문에 스마트 시티 참여 기업의 ESG 수준을 비교 분석함으로서 스마트시티에 참여하려는 기업에게 지속가능경영에 대한 동기를 부여할 수 있다.

Keywords : 스마트시티, 지속가능도시, 환경·사회·거버넌스 (ESG), 다중선형회귀분석

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